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Final Report: Mobile Surveillance and Wireless Communication Systems Field Operational Test

Volume 2: FOT Objectives, Organization, System Design, Results, Conclusions, and Recommendations

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Preface

The Mobile Surveillance and Wireless Communication Systems Field Operational Test (FOT) contained two evaluation tests, the Anaheim Special Event Test and the Interstate-5 (I-5) Test. The Anaheim Special Event Test assessed the ability of the surveillance trailers to transmit video imagery to a traffic management center in support of arterial traffic signal control. This test occurred during the Spring of 1997 in conjunction with heavy traffic experienced during hockey playoff games at the Arrowhead Pond in Anaheim, CA. The I-5 Test evaluated the ability of the mobile surveillance and ramp meter trailers to transmit video imagery and data in support of freeway ramp metering. It occurred a year later in Spring 1998 along I-5 in Orange County, CA. The results of these tests and other conclusions from the FOT are presented in three volumes. The first volume serves as the Executive Summary of the FOT. It describes the project objectives, results, conclusions, and recommendations in condensed fashion. The second volume discusses the overall goals and objectives of the FOT and the design of the mobile surveillance and wireless communication system in more detail. Technical and institutional issues that surfaced before either of the two FOT tests was conducted are described. The specific objectives of the Anaheim Special Event and the I-5 Tests, lessons learned, test results, and recommendations are expanded upon in this volume. Photographs and drawings are used liberally to illustrate the types of equipment and test configurations that were tested. Volume 2 also incorporates revisions to the evaluation plans that were originally prepared by Pacific Polytechnic Institute (PPI). The evaluation plans and preliminary results from the planning and design phases of the FOT and the Anaheim Special Event Test were originally published by California Partners for Advanced Transit and Highways (PATH) under Report 97-C34. The third volume consists of ten appendices that contain data and other information gathered during the tests.

The test planning and execution were a cooperative effort among the partner agencies and companies. These were the Federal Highway Administration, California Department of Transportation divisions in Sacramento and Orange County, California Partners for Advanced Transit and Highways, University of California at Irvine Institute of Transportation Studies, California Highway Patrol, City of Anaheim Department of Public Works, Hughes Aircraft Company (now Raytheon Systems Company), Pacific Polytechnic Institute, and Lawrence A. Klein, Consultant.

This report was prepared in cooperation with the State of California, Business Transportation and Housing Agency, Department of Transportation. The material is based on work supported by the Federal Highway Administration, the State of California, Department of Transportation under prime contract number RTA-65A0012, and the Regents of the University of California.

Synopsis of Project

The Mobile Surveillance and Wireless Communication Systems Field Operational Test (FOT) evaluated the performance of wireless traffic detection and communications systems in areas where permanent detectors, electrical power, and landline communications were not available. The FOT partners designed and built six surveillance and three ramp meter trailers, a video and data retransmission or relay site, and video and data reception facilities at the Caltrans District 12 and Anaheim Traffic Management Center (TMCs) and the University of California at Irvine Institute of Transportation Studies (UCI-ITS) Laboratory. The system was evaluated in two different types of tests. The Anaheim Special Event Test assessed the surveillance trailers in an application that transmitted video imagery in support of arterial traffic control during a special event. The Interstate-5 (I-5) Test examined the use of the mobile surveillance and ramp meter trailers to transmit video imagery and data in support of freeway ramp metering.

The primary tasks of the surveillance trailer are to acquire video imagery and traffic data, transmit metering rates to the ramp meter trailer, and transmit traffic flow data and imagery to the relay site. The major components of the surveillance trailer are a video image processor (VIP); two pan and tilt black-and-white cameras; one pan, tilt, and zoom color camera; one fixed black-and-white security camera; a 170 controller; wide and narrow bandwidth spread spectrum radios (SSRs) for video and data transmission; a telescoping 30-foot (9.1-meter) mast; a security system; and a propane-powered electrical generator and power supply system. The ramp meter trailer retransmits the metering rates to portable signal heads on the ramp and controls the meter-on sign. The major components of the ramp meter trailer are two traffic signal heads, a ramp meter-on sign, narrow band SSRs for data reception, and solar-powered electrical recharging systems for one signal head and the meter-on sign. The relay site on the Union Bank Building in Santa Ana, CA supports trailer locations along the I-5 reconstruction zone in Orange County, CA. Video imagery and data received at the relay site are retransmitted to the TMCs and to the UCI-ITS Laboratory.

Perhaps the biggest issue faced by the project was the schedule delay. This was mainly attributed to deficiencies in the planning and procurement processes and the changes in scope that persisted well into the procurement and integration phases of the project. 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. Closely related to the planning issues was the conflict over whether the FOT was developing prototypes or completely developed equipment that could support normal transportation management operations.

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. 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, the current existence of only one relay site limits the areas in which the trailers can be deployed. 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.

The item that most impacted the start of the I-5 Test once the trailers were deployed was the initial lack of ramp signal synchronization with vehicle demand and control commands from the surveillance trailer. The problem was remedied by reducing the transmission rate of the commands.

The most prevalent problem uncovered during the I-5 Test was frequent discharge of the surveillance trailer battery. 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.

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

The average percent differences between the permanent inductive loop detector (ILD)- and VIP-measured mainline total volume and average lane occupancy were –22 and 8, respectively, based on data gathered in 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 metering rates produced by the ILD and VIP data. These errors were tolerable because a more restrictive metering rate (namely zero) than the prestored time-of-day (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.

The larger mainline volume measured by the VIP as compared to the ILD 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. Therefore, a method of compensating for vehicle overcount by the VIPs is needed in order to report valid mainline traffic volumes.

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, and hence the camera, closer to the ramp. This may provide a better perspective of the vehicles on the ramp and perhaps modify the camera’s field of view to allow even more VIP detection zones to be created upstream of the ramp stop bar. The multiple detection zones can then be connected with OR logic to increase the probability that a stopped vehicle will be detected by the VIP.

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.

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1. Objectives and Project Organization

1.1 Introduction

Traditional inductive loop detectors and landline communications can be costly to maintain, are subject to damage and removal during construction, and generally cannot provide cost-effective surveillance and communications at special events or remote locations where these detectors and communications systems are not already in place. In the Mobile Surveillance and Wireless Communication Systems Field Operational Test (FOT), the California ITS partners designed, built, and evaluated a mobile trailer system that provides closed-circuit television surveillance, video image processing, inductive loop emulation, ramp metering, and communication of data and video imagery to transportation management centers and research facilities. The mobile system consists of surveillance and ramp meter trailers, a retransmission or relay site, and data reception facilities. The salient features of the system are:

- Mobile trailers that can be deployed to locations that have line-of-sight communications with a relay site;
- A color camera that provides surveillance of traffic conditions, two black-and-white cameras that supply imagery to a video image processor (VIP), and a black-and-white camera used for trailer security;
- Video image processing of freeway mainline and onramp traffic to detect vehicles, control metering rates, and extract traffic volume, lane occupancy, and vehicle speed at construction areas, special events, or any other site where permanent vehicle detection systems are not installed or operating;
- Inductive loop emulation by the VIP to facilitate the incorporation of data into existing traffic management systems;
- Wireless spread spectrum radio (SSR) communications between surveillance and ramp meter trailers and between the trailers, traffic management centers, and research facilities.

The mobile surveillance and wireless communication system was tested under real traffic conditions on Orange County, CA freeways and Anaheim, CA arterial roadways in two tests. The Anaheim Special Event Test evaluated the ability of the surveillance trailers to provide video imagery in support of traffic management on arterial streets during a preplanned event. In the Interstate-5 (I-5) Test, the surveillance and ramp meter trailers were used to provide local-responsive ramp metering. During these tests, the wireless communication system transmitted traffic flow data and imagery to the California Department of Transportation (Caltrans) and California Highway Patrol (CHP) District 12 (Orange County) Transportation Management Center (TMC), the City of Anaheim TMC, and the University of California at Irvine Institute of Transportation Studies (UCI-ITS) Laboratory.

The Final Report was developed according to the FHWA Intelligent Vehicle Highway Systems Operational Test Evaluation Guidelines of November 1993. Three test evaluation and planning documents and an interim draft Final Report were also prepared by the evaluators. These were the *Overall FOT Evaluation Plan*, *Anaheim Special Event Test Evaluation Plan*, *I-5 Test Evaluation Plan*, and *Evaluation Report for Mobile Surveillance and Wireless Communication Systems Field Operational Test*, Interim Draft.

1.2 Other Portable Traffic Management Systems Designed for Temporary Use in Construction Areas

Two other mobile traffic management systems have been developed in recent years. FHWA and the Minnesota Department of Transportation sponsored the first and the Iowa DOT and FHWA sponsored the second.

1.2.1 Portable Traffic Management System

The Portable Traffic Management System (PTMS) application for a Smart Work Zone was developed by MnDOT with support from FHWA.[1] The project partners also included the University of Minnesota, ADDCO, ISS, Vano Associates, BRW, and SRF Consulting Group. The PTMS integrates existing, off-the-shelf, and emerging traffic management technologies into a wireless, portable traffic control system. It operates in a work zone and provides traffic engineers with speed, volume, and incident detection data that are communicated to the traveling public so that they may make informed travel decisions.

As developed for the work zone application, the PTMS consists of portable skids that contain a machine vision system, variable message sign (VMS), central processing unit (CPU), and spread spectrum radio communications. The skids are placed in strategic locations in the work zone and, when linked to one another by the spread spectrum radio, form nodes in the PTMS network. The nodes can include both vehicle detection devices and driver information devices. Figure 1-1 shows the PTMS skid deployed in the work zone with both types of devices installed. The inset in Figure 1-1 shows a close up of the top of the PTMS tower. The CPU and related components are housed in the cylindrical enclosure.

The PTMS consists of four subsystems: vehicle detection and surveillance, traffic control center, driver information, and communications. The vehicle detection and surveillance subsystem contains cameras and a video image processor. Video cameras placed at strategic locations in the work zone provide real-time traffic flow information to traffic management personnel. The video image processor analyzes the camera imagery to produce traffic volume, speed, incident detection, and alarms that indicate vehicle intrusion into the work zone. The camera is mounted at the top of the tower as illustrated in the left side of the inset in Figure 1-1.

The data from the vehicle detection and surveillance subsystem are transmitted to the traffic control center at the MnDOT Traffic Management Center. After review, operators use the data to make decisions regarding traffic control that are intended to improve traffic flow through the work zone. The traffic control changes are implemented by relaying messages to the motorist through the driver information subsystem that consists of full-size portable, variable message signs and smaller work zone portable variable message signs. The information can also be made available to the public on a World Wide Web page via the Internet.

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1. *Portable Traffic Management System Smart Work Zone Application Operational Test Evaluation Report*, SRF Consulting Group, Report Number 0942089.7/11, May 1997.

Figure 1-1. PTMS deployed on a skid
(From *Portable Traffic Management System Smart Workzone Application, Final System Design Report*, MnDOT, May 1997)

The communications subsystem utilizes spread spectrum radio, cellular telephone, and the Integrated Services Digital Network (ISDN). The spread spectrum radio antenna is mounted at the top of the tower as shown on the inset in Figure 1-1. Each of the communication devices is used for specific links. This subsystem will eventually include a master controller and a radio link to the traffic control center.

The costs for the PTMS are summarized in Table 1-1. The minimum configuration for a PTMS requires the basic system, base station, and landline communications and control packages. The cost for this configuration is $75,850.

1.2.2 Rural Smart Work Zone

During the 1997 Interstate-80 reconstruction in Iowa, traffic engineers acted to mitigate the impact of traffic incidents in the work zone and reduce the number of secondary traffic accidents. The increased incidents and secondary accidents were caused by reduced work zone capacity, which combined with peak period demand to create traffic backups that brought about the accidents. Prior to the development of the Rural Smart Work Zone, traffic monitoring was provided by a single person in a roving vehicle who monitored traffic and responded to observed incidents. The single roving vehicle technique, by itself, was inadequate for the large reconstruction area.

Table 1-1. Portable Traffic Management System costs (MnDOT project)

System	Cost
Basic System containing skid mount platform and 40-foot (12.2-meter) tower; CCTV camera, enclosure, pan, tilt, zoom assembly; video compressor and control processor; 900 MHz SSR communications; 600 W tilt and rotate solar panel with 3520 amp-hour battery	$59,850
Base Station, Landline Communications, and Control System containing solar powered pole mount relay and termination; two ISDN routers, ADDCO Base Station Software	$16,000
Optional systems:	
3 x 6 foot, 24 x 48 pixel LED message sign	$9,800
AutoScope with field upgrade kit	$21,700
Speed (Doppler) radar	$2,000
Skid trailer assembly	$4,000

The Rural Smart Work Zone consists of an incident detection unit (IDU) equipped with a Whelen microwave Doppler sensor to measure vehicle speed and a camera to acquire images of the traffic flow.[2] When speeds drop below 35 mi/h (56.3 km/h), the IDU automatically places a series of four cellular telephone calls, three to activate Automated Traveler Information System (ATIS) devices [namely, two mobile changeable message signs (CMS) and a highway advisory radio (HAR)] and one to notify the roving vehicle. The camera operates independently of the speed sensor. The images from the camera can be viewed (for example, at the TMC) by calling the camera via cellular telephone. The images are transmitted by cellular communications as well. The viewer can select the image refresh rate up to a maximum of once every 2 to 3 seconds. Cellular communications was used because of the required transmission distances. CMS #1 is two miles from the IDU, CMS #2 is 10 miles (16.1 km) from the IDU, and the HAR is 20 miles (32.2 km) from the IDU.

The camera and its interface to the cellular communications system were provided by Denbridge Digital of San Leandro, California. The Iowa DOT reports that the camera portion of the IDU has performed well. The Doppler sensor with its link to the cellular system was provided by Display Solutions (the CMS supplier). The sensor-cellular system fails whenever there is a temporary disruption in traffic flow. The problem arises because it takes a certain amount of time for the telephone to place the four cellular calls. If traffic clears [speeds rise above 35 mi/h (56.3 km/h)] before all four calls are completed, the system locks up. Iowa is attempting to remedy this problem. However, Display Solutions may have decided to discontinue their participation in the sensor market and may not support the product further. No formal evaluation was required or performed.

1.3 Goals and Objectives of the Mobile Surveillance and Wireless Communication Systems FOT

The goals and objectives for the Mobile Surveillance and Wireless Communication Systems FOT were derived from those of the National ITS Program, namely:

2. S.J. Gent, "Rural Smart Work Zone," *ITE Journal*, p. 18, Jan. 1998.

- Improve the safety of the Nation's surface transportation system;
- Increase the operational efficiency and capacity of the surface transportation system;
- Reduce energy and environmental costs associated with traffic congestion;
- Enhance present and future productivity;
- Enhance the personal mobility and the convenience and comfort of the surface transportation system; and
- Create an environment in which the development and deployment of ITS can flourish.

These program goals are expanded in ITS America's *Strategic Plan for Intelligent Vehicle-Highway Systems* and in the U.S. Department of Transportation's *IVHS Strategic Plan*.[3]

The overall goal of this FOT was to assess the application of traffic monitoring and management systems that utilize transportable surveillance and ramp meter trailers, video image processors, and wireless communications. This goal is consistent with the national objectives described above. For example, the FOT tested and evaluated technology that is designed to increase the operational efficiency of the freeway system by providing a ramp-metering system suitable for temporary deployment in construction zones. The FOT was conducted within the California ITS Test Bed, an area in Orange County containing both freeways and surface streets, that has been specified by Caltrans for the development and evaluation of ITS products. Therefore, the FOT occurred in an environment that was designed for the development and deployment of intelligent transportation systems.

1.3.1 Anaheim Special Event Test Objectives

The Anaheim Special Event Test had five objectives:

1. Examine the portability of the surveillance and ramp meter trailers for installation in a city pre-planned special event setting within range of the communications relay site;
2. Demonstrate that the surveillance and ramp meter trailers are effective in supporting pre-planned special event traffic management where traditional traffic monitoring systems are not otherwise available;
3. Assess the relative impact of additional video surveillance with respect to special event traffic management;
4. Examine the institutional issues, benefits, and costs associated with sharing resources between agencies in a special event setting;
5. Examine the institutional issues, benefits, and costs associated with sharing information between allied agencies.

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3. *Strategic Plan for Intelligent Vehicle-Highway Systems in the United States*, Final Draft (First Version), ITS America, Washington, D.C., March 25, 1992.

1.3.2 I-5 Test Objectives

The I-5 Test had the following four objectives:

1. Examine the portability of the surveillance and ramp meter trailers for installation in a freeway setting within range of the communications relay site;

2. Demonstrate that the surveillance and ramp meter trailers are effective in that they may be used for freeway traffic management where permanent traffic surveillance and control systems may be disabled or not otherwise available;

3. Examine the institutional issues, benefits, and costs associated with surveillance and ramp meter trailer deployment in a freeway setting;

4. Examine the institutional issues, benefits, and costs associated with information sharing in a freeway setting.

1.4 FOT Design

The FOT deployed surveillance and ramp meter trailers to selected locations and transmitted data and video imagery from multiple sites, in real-time, to TMCs and the UCI-ITS Laboratory. The FOT evaluated the operational effectiveness of the trailers for real-time traffic management on freeways and in special event settings that required traffic control on city arterials.

1.4.1 Anaheim Special Event Test Design

In the Anaheim Special Event Test, three surveillance trailers were placed on streets that fed traffic into the Arrowhead Pond in Anaheim, indicated on Figure 1-2. Only camera imagery was of interest in this test. The video was transmitted to the Anaheim and Caltrans District 12 TMCs during evenings when the Anaheim Mighty Ducks were involved in hockey playoff games. Anaheim had primary control of the trailer locations and cameras during this test as the emphasis was on controlling traffic ingress and egress operations to and from the streets and parking lot areas near the Pond.

1.4.2 I-5 Test Design

In the I-5 Test, surveillance and ramp meter trailers were located at six evaluation sites along a 7-mi (11.3-km) length of I-5 between State Route (SR)-22 and Culver Drive in Orange County, CA as shown in Figure 1-2. Video images of traffic flow and traffic flow data were transmitted to the Caltrans District 12 TMC, Anaheim TMC, and the UCI-ITS Laboratory. Caltrans had primary control of the cameras during the I-5 Test. Emphasis was on weekday, peak-period traffic operations.

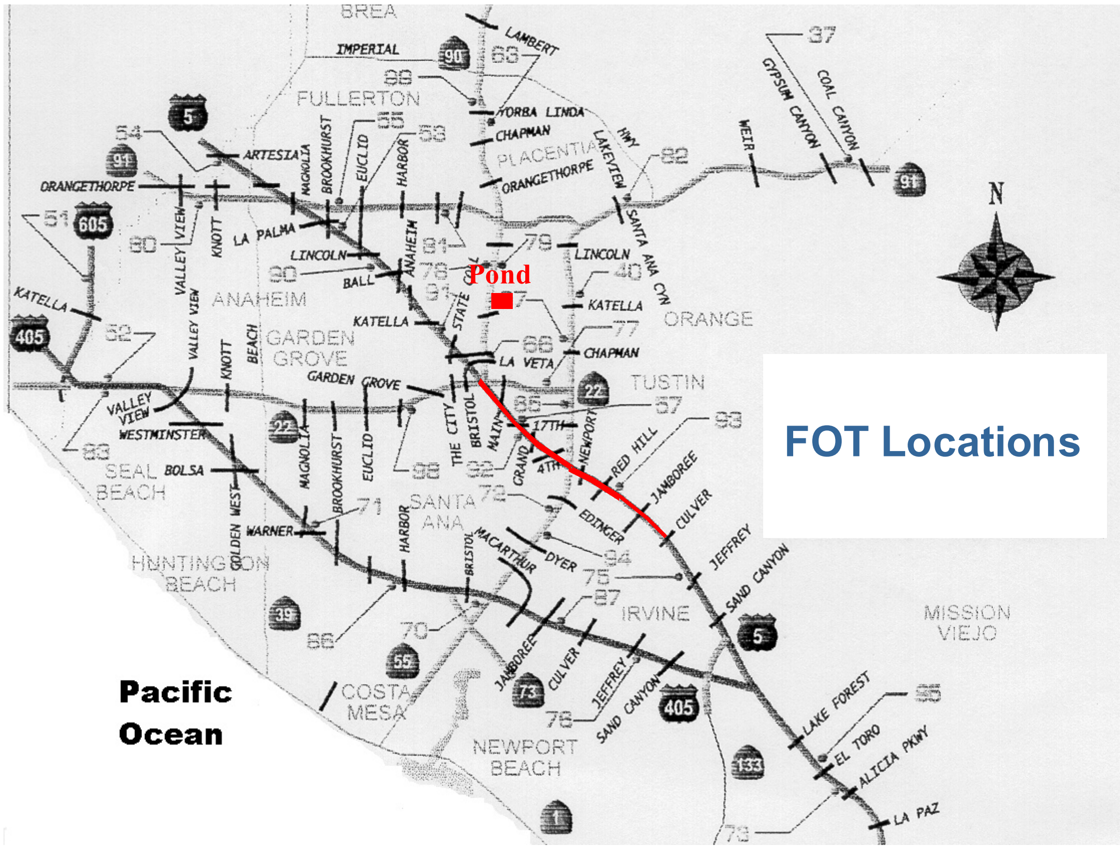


Figure 1-2. FOT locations

All six surveillance trailers and all three ramp meter trailers were used in this test. Three surveillance trailers were paired with ramp meter trailers at three onramps along the freeway. These surveillance trailers used SSRs to transmit camera imagery and VIP-generated traffic flow data to the TMCs and UCI. They also used SSR to transmit metering rates to the ramp meter trailer, which in turn controlled the ramp signals and the meter-on sign. The remaining three surveillance trailers were placed at other strategic venues along the freeway. These trailers transmitted only imagery to the TMCs and UCI.

1.5 Mobile Surveillance and Wireless Communication System Design and Operation

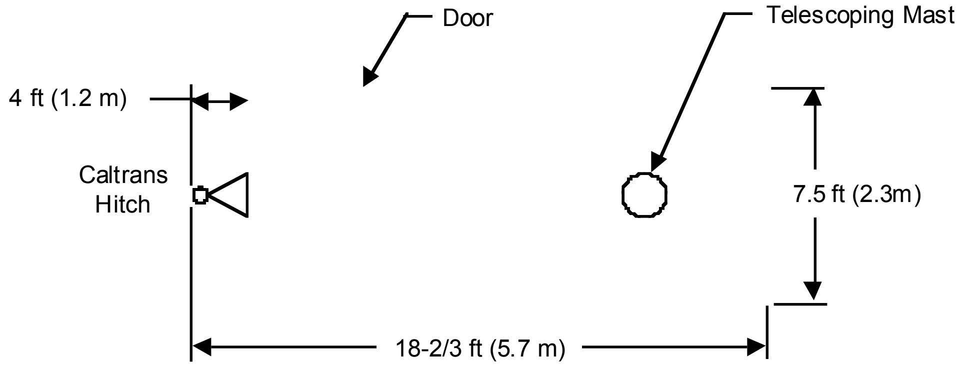
The mobile surveillance and wireless communication system consists of surveillance and ramp meter trailers, a video and data retransmission or relay site, and video and data reception facilities at TMCs and the UCI-ITS research laboratory. Six surveillance and three ramp meter trailers were assembled as part of the FOT. Figure 1-3 shows a surveillance trailer. Its major components are a video image processor; two pan and tilt black-and-white cameras; one pan, tilt, and zoom color camera; one fixed black-and-white security camera; a 170 controller; wide and narrow bandwidth spread spectrum radios for video and data transmission; a telescoping 30-foot (9.1-meter) mast; a security system; and a propane-powered electrical generator and power supply system.

Figure 1-3. Surveillance trailer at First Street overlooking I-5 Freeway

Figure 1-4 shows a ramp meter trailer. Its major components are two traffic signal heads, a ramp meter-on sign, narrow band SSRs for data reception, and solar-powered electrical recharging systems for one of the signal heads and the meter-on sign.

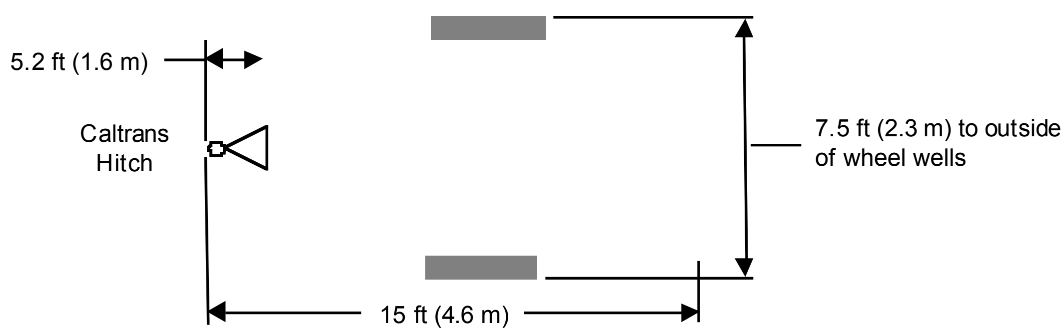
Figure 1-4. Ramp meter trailer at Grand Avenue alongside I-5 Freeway

Trailer dimensions are displayed in Figure 1-5. The surveillance trailers can operate autonomously of the ramp meter trailers and thus be used in applications that do not require ramp metering. Each surveillance trailer can support two ramp meter trailers. However, in this FOT the surveillance trailers were programmed to operate only one ramp meter trailer.



A fully-extended mast is 30 ft (9.1 m) high.
Since the floor of a surveillance trailer is approximately 2 ft (0.6 m) above the ground, the top of a fully-extended mast is approximately 32 ft (9.8 m) above the ground.
The roof of the surveillance trailer is 8-2/3 ft (2.6 m) above the ground.
The railing on the surveillance trailer roof is 3 ft (0.9 m) high.

(a) Surveillance trailer dimensions



(b) Ramp meter trailer dimensions

Figure 1-5. Trailer dimensions

The primary tasks of the surveillance trailer are to acquire traffic video imagery and data, transmit metering rates to the ramp meter trailer, and transmit traffic flow data and imagery to the relay site. The ramp meter trailer retransmits the metering rates to the signal heads and controls the meter-on sign. The primary signal head is connected by cable to the ramp meter trailer; the secondary signal head receives its commands via SSR from the ramp meter trailer. The meter-on sign receives its commands via an FM radio transmitter/receiver pair.

The relay site receives traffic flow data and imagery from the trailers and retransmits them to the state and city TMCs and the UCI-ITS Laboratory. The relay site on the Union Bank Building in Santa Ana, CA supports trailer locations along the I-5 reconstruction zone in Orange County, CA providing line-of-sight transmission exists.

Depending on their equipment, the TMCs and UCI may have remote surveillance trailer control, remote camera control, and remote VIP calibration control. Remote surveillance trailer control includes trailer selection, power-up, power-down, mast-extend, and mast-retract control. Remote camera control includes image selection for display at the TMC and pan, tilt, and zoom control of the surveillance camera. Remote VIP calibration control includes video detection zone configuration and the ability to receive VIP data.

The Caltrans District 12 TMC is the only facility that can exercise all remote control options, namely remote trailer, camera, and VIP control. The Anaheim TMC has remote trailer and camera control, but lacks remote VIP control. The UCI-ITS Laboratory does not presently have any remote control capability. While researchers at UCI are able to view camera images, they must contact either the Caltrans District 12 TMC or the Anaheim TMC for assistance in selecting a particular image or scene transmitted by the SSR system. However, the UCI-ITS Laboratory can also receive imagery and data over a separate fiber optics backbone connected to Caltrans.

Table 1-2 lists the SSRs used in the mobile system to facilitate communications between surveillance and ramp meter trailers, the relay site, and the TMCs and UCI. The various video and data transmission paths are illustrated in Figure 1-6.

Table 1-2. Spread spectrum radios used in the mobile surveillance and wireless communications system

Manufacturer and Model	Qty	Spectrum	Bandwidth/ Channel	Location	Information
Cylink 19.2 ALM	1	902-928 MHz	1.5 MHz	Surveillance trailer	Metering and control data
Cylink 64 ALSM	1	2.4-2.48 GHz	5.1 MHz	Surveillance trailer	Data
Cylink 256 NSPALS	1	2.4-2.48 GHz	20.5 MHz	Surveillance trailer	Video
Cylink 19.2 ALM	1	902-928 MHz	1.5 MHz	Ramp meter trailer	Control data
Digital Wireless WIT915	2	902-928 MHz	1 MHz	Ramp meter trailer	Signal light control
Cylink 64 ALSM	2	2.4-2.48 GHz	5.1 MHz	Relay site	Data
Cylink 256 NSPALS	3	2.4-2.48 GHz	20.5 MHz	Relay site	Video
Cylink ALT1	1	5.725-5.850 GHz	125 MHz	Relay site	Data and video
Cylink ALT1	1	5.725-5.850 GHz	125 MHz	District 12 TMC	Data and video
Cylink 64 ALSM	1	2.4-2.48 GHz	5.1 MHz	Anaheim TMC	Data
Cylink 256 NSPALS	1	2.4-2.48 GHz	20.5 MHz	Anaheim TMC	Video
Cylink 64 ALSM	1	2.4-2.48 GHz	5.1 MHz	UCI-ITS	Data
Cylink 256 NSPALS	1	2.4-2.48 GHz	20.5 MHz	UCI-ITS	Video

The two pan and tilt black-and-white cameras on each surveillance trailer supply imagery to the VIP. In freeway operations, one camera is usually pointed at the mainline and the other at an onramp. For arterial applications, each camera can be pointed at a different approach to an intersection. Once the detection zones are calibrated, the black-and-white cameras are not repositioned. In fact, the control cables are removed from the pan and tilt units for these cameras to prevent accidental camera movement once the VIP is operational.

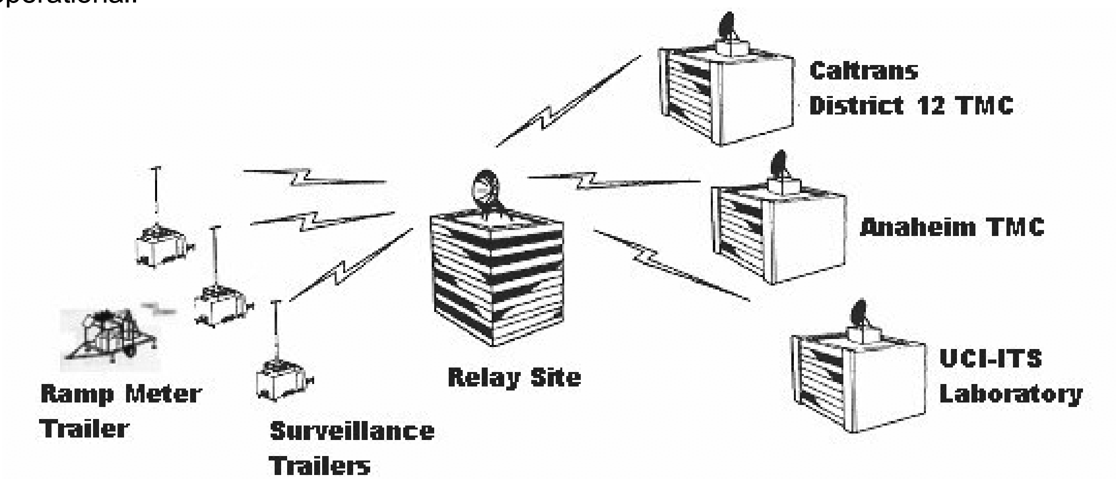


Figure 1-6. Transmission of video and data among trailers, relay site, TMCs, and UCI

(Adapted from *System Information Manual, Mobile Video Surveillance Communications System*, Hughes Aircraft Company, Feb. 1998)

The pan, tilt, and zoom color camera is used for traffic flow surveillance. The fixed position black-and-white security camera is pointed at the surveillance trailer door to enable TMC personnel to observe trailer entry. The surveillance trailers contain a security system that is connected to the Caltrans District 12 TMC. Up to two cameras from among a total of twenty-four (four at each of the six surveillance trailers) can be selected by the District 12 TMC to simultaneously transmit and display video imagery. Imagery from one camera can be selected for display by the Anaheim TMC. This concept is shown in Figure 1-7.

Figure 1-8 contains photographs of the two racks of equipment found in each of the surveillance trailers. The rack on the left contains the power distribution system, spread spectrum radios that transmit data to the ramp meter trailer and relay site, wide-area communications controller, AutoScope 2004 VIP, and the170 controller that processes the VIP data. The rack on the right contains a monitor, controls for selectively displaying the imagery from the color surveillance camera or the black and white VIP cameras on the monitor, digital video encoder, spread spectrum radio that transmits compressed video imagery to the relay site, pan-tilt-zoom camera controls, generator auto start/battery recharge system, and the automatic mast retraction circuit.

The video image processor analyzes the images of mainline and ramp traffic and provides traffic flow volume, lane occupancy, and vehicle speed to the 170 controller located in the surveillance trailer. The format of the VIP data is the same as that produced by permanent inductive loop detectors. Therefore, the VIP data are compatible for utilization by existing traffic control systems.

Since the surveillance and ramp meter trailers are self-powered and use wireless communications, they can be located where normal electric power and landline communications are not available. Thus, the equipment can replace in-pavement loop systems temporarily rendered inoperative at construction sites and supplement existing traffic control systems at special pre-planned events or at long-duration emergencies. The system can also provide data for traffic management research.

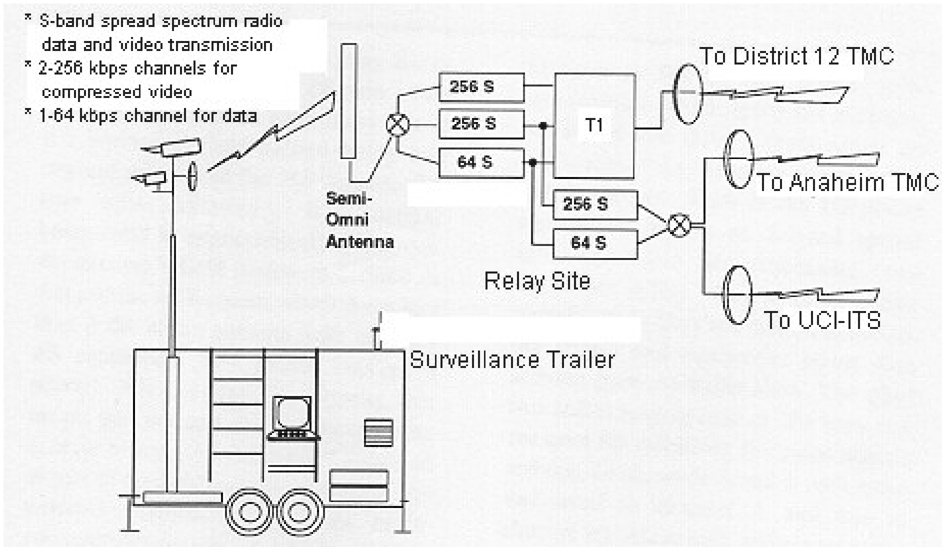


Figure 1-7. Selection of video images for transmission from surveillance trailers to TMCs and UCI. Video images from two cameras on any of the six surveillance trailers reach the District 12 TMC, while one camera image is transmitted to the Anaheim TMC and UCI.
(Adapted from *System Information Manual, Mobile Video Surveillance Communications System*, Hughes Aircraft Company, Feb. 1998)

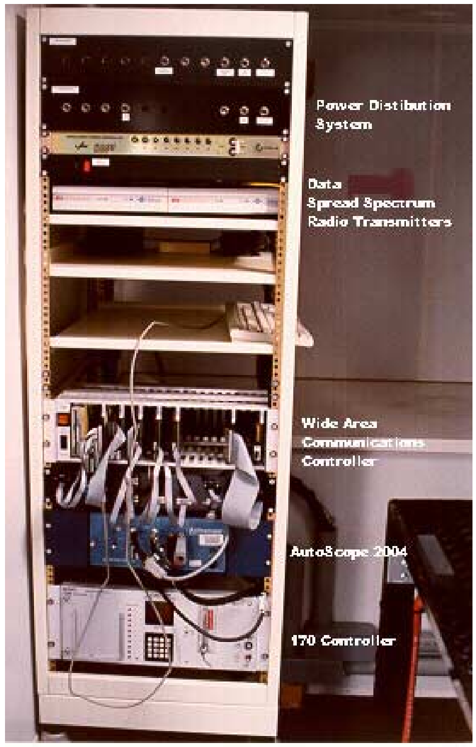
The trailers and relay site operate without human operator intervention. As such, the surveillance and ramp meter trailers can be programmed to turn on and off automatically using the 170 controller. Outside of designated metering times, the associated surveillance trailers can be turned on and off remotely from the TMCs as needed.

1.6 Project Management

The FOT was a cooperative effort among the test partners. The Federal Highway Administration (FHWA) and Caltrans sponsored the FOT. Other partners included California PATH, University of California at Irvine, Hughes Aircraft Company (now Raytheon Systems Company), City of Anaheim, the California Highway Patrol, Pacific Polytechnic Institute (PPI), and Lawrence A. Klein, Consultant (LAK). The partners were arranged into three teams: the Project Management Team, the Evaluation Team, and Technical Review Team. While each team had responsibilities that were distinct, the three teams worked as a group to support the objectives of FOT.

The Project Management Team (PMT), which included Caltrans, Hughes, FHWA, Anaheim, and UCI, was responsible for conducting the FOT. As such, they deployed and operated the surveillance and ramp meter trailers, assisted in test design, and collected test data. The PMT also provided the Evaluation Team with written reports on test activities, technology issues, institutional issues, and costs.

The Evaluation Team, which included PPI (later LAK), PATH (later UCI), and FHWA, was responsible for performing an independent evaluation of the FOT. PPI performed the independent evaluation from April 1994 through June 30, 1997. A contract to complete the independent evaluation was issued to Lawrence A. Klein for the



(a) Left equipment rack

(b) Right equipment rack

Figure 1-8. Surveillance trailer equipment racks

September 1, 1997 through April 30, 1999 period. PPI and LAK were the members of the Evaluation Team responsible for coordinating the collection of test data and preparing test procedures and reports. In this role, PPI and LAK provided the PMT with comments about the test design, observed test activities, analyzed test data, interviewed test participants, and prepared the final reports. California PATH served as evaluation manager, through a contract with Caltrans, when PPI was the evaluator. UCI-ITS served as the evaluation manager, also through a contract with Caltrans, when LAK was the evaluator. FHWA and its contractor, Booz-Allen & Hamilton, reviewed and approved test plans and reports. UCI retained Hughes to provide engineering services for the design, installation, and systems integration of the equipment.

The Technical Review Team (TRT), which included Caltrans and Anaheim, was responsible for reviewing technical issues related to the planning, design, and execution of the FOT. Members of the TRT were selected for their ability to assist in evaluating project objectives, plans, and evaluation procedures.

1.7 Evaluation Focus

Remote traffic surveillance by itself does not result in direct operational benefits. Traffic flow measurements and video surveillance produce benefits to freeway traffic management only when freeway operations personnel use the information appropriately. In the Caltrans District 12 TMC, Caltrans and CHP operators review all available incident and traffic information, coordinate activities with allied personnel, and refer to standard operating procedures in order to initiate traveler advisories and other traffic management decisions. The objective of their actions is to help preserve freeway safety and expedite the movement of freeway traffic.

The FOT partners focused the FOT evaluation on functions that are unique to the mobile surveillance and ramp meter trailers, wireless transmission of data and imagery, and the relay site. As such, the evaluation did not investigate the benefits of providing traffic surveillance video and data to operations facilities, nor did it explore the benefits of ramp metering or a comparison of VIP and inductive loop detector accuracies. Rather, the focus was on features such as transportability, self-contained power, wireless communications, and the ability to provide video and data that are of sufficient accuracy to support local-responsive ramp metering and the arterial traffic management goals of the FOT. Other issues explored dealt with the sharing of real-time video and data among traffic operations and research facilities.

1.8 Revisions to the FOT

The FOT partners initiated a series of revisions that affected the ultimate design of the FOT and the evaluation. The original plans included two segments. Segment 1 specified deployment of six surveillance trailers, three ramp meter trailers, and a vehicle-to-roadway communication (VRC) system. Segment 2 provided the option to deploy an additional nine surveillance trailers and an additional three ramp meter trailers on the condition that both FHWA and Caltrans agreed to extend their participation. Ultimately, the FOT partners decided to forego VRC deployment in Segment 1 and to omit Segment 2.

The VRC system was to include 500 transponders and 2 roadside readers. Five hundred vehicles were to be equipped with the transponders for use as probes. These probe vehicles would then provide an independent measure of traffic flow conditions within the I-5 construction zone. The partners agreed that the VRC measurements were not needed primarily because construction near the test sites was completed before the FOT evaluation could begin. Consequently, traditional surveillance systems had been restored and were available if an independent measure of traffic conditions was needed. Furthermore, the partners concluded that the independent measurement was no longer important since the FOT objectives had been revised away from issues associated with improved traffic flow. The objectives now were oriented towards transportability, setup, and effectiveness of the mobile system.

The FOT partners decided not to proceed with Segment 2 because delays had extended the FOT beyond the time when Segment 2 was feasible. The decision to omit Segment 2 affected the design of the field evaluation tests. The original FOT included three field tests. The Anaheim Special Event Test specified that the mobile surveillance trailers be deployed in the City of Anaheim to evaluate their potential to assist in the management of special event traffic. The I-5 Test required the mobile surveillance and ramp-metering trailers be deployed along a freeway where traditional loop detectors were disabled due to construction. A third test was conceived for using the mobile surveillance trailers along SR-91. This test was to evaluate issues related to the gathering and synchronization of data from successive trailer locations. When the FOT partners decided not to proceed with Segment 2, they also eliminated the SR-91 Test as it required the installation of one or more additional relay sites to support wireless communication along SR-91.

2. General Issues

Technical and institutional issues that are not specific to either the Anaheim Special Event or I-5 Tests are discussed in this section. A summary of the equipment costs for the surveillance and ramp meter trailers, the District 12 and Anaheim TMCs, the UCI-ITS Laboratory, and the relay site is also provided.

The issues below are addressed in this chapter:

1. Planning and Scheduling
2. Definition of Test Objectives
3. Cost Centers and Personnel-Year (PY) Allocations
4. Equipment Procurement
5. Trailer Hitch Redesign and Replacement
6. Portable Power Generation System
7. Automatic Mast Retraction
8. Caltrans TMC System Integration
9. Data Capture and Presentation
10. Shared Camera Selection and Control Among Agencies
11. Relay Site
12. Trailer Security
13. Technical Training
14. Trailer Transport and Setup
15. Ramp Meter Trailer Design
16. Equipment Costs

2.1 Planning and Scheduling

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.

Allotting more time to incorporate each increase in scope in the trailer's function would have allowed the contractor to adequately design, fabricate, and test each subsystem before it was integrated into the entire mobile system. Furthermore, 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. Lack of early testing of some surveillance and communications subsystems postponed the timely identification of problems, thereby creating delays for other FOT tasks.

The increase in time needed to complete the FOT was somewhat exacerbated by retirements and personnel reductions at Hughes. Consequently, there were four program managers assigned over the life of the project by Hughes. Although Hughes made every effort to transfer the details of the program to succeeding managers, some discontinuity and program delay were caused by the personnel changes.

2.2 Definition of Test Objectives

The FOT partners spent considerable time revising and finalizing the test objectives. Initially, the objectives dealt with measuring the improvement in traffic flow that resulted when the trailers were deployed in a special event area and a construction zone. Due to project delays, the construction at the designated I-5 Test locations was completed and traditional detection methods restored before the test could start. It was agreed that the I-5 Test continue as planned although construction in the selected freeway area was complete. This decision was made in order to avoid the complications of finding new locations for the trailers in ongoing reconstruction zones and testing for adequate signal strength. However, an added benefit was obtained by staging the test in the completed work area. This was the ability to compare ramp-metering rates calculated from VIP and permanent ILD measurement data.

The change in test conditions sparked considerable discussion about using the trailers to measure the benefits of mobile vehicle detection and traffic surveillance. The Evaluation Team recognized that surveillance alone delivers no operational benefit and that surveillance provides operational benefits only when the information is utilized by skilled personnel to manage traffic. It then became unclear how to distinguish the use of data from mobile detection and surveillance from data gathered with permanent detection and surveillance techniques. The Project Management Team also struggled with how to separate the contribution from the surveillance trailers from the contribution of traffic managers and their customary control systems.

The FOT partners then began to focus on the system attributes that were unique to the FOT including trailer transportability, use at special events, and sharing of video and data among multiple agencies through wireless communications. The final set of test objectives, as presented in Section 1.3, reflects this perspective.

2.3 Cost Centers and Personnel-Year (PY) Allocations

Caltrans District 12 maintenance and electrical personnel were important assets to the FOT partnership. Their expertise contributed to resolving design issues, such as the trailer hitch, and to the relative ease in transporting the trailers. Unfortunately, some maintenance and electrical personnel indicated that they initially had difficulty in making these contributions as no cost center was available for charging time spent on FOT activities. These personnel were assigned additional tasks without having the financial resources to support the work. At one point, the Electrical Supervisor instructed his personnel to refuse to work on the FOT explaining that the person-year (PY) allocations their department had been given were insufficient to support the FOT and their regular work load. Personnel previously relied on to perform routine trailer maintenance had also been told by their supervisors to adhere to Caltrans restrictions that prohibit them from performing such tasks. This issue was eventually resolved when appropriate accounts were established.

2.4 Equipment Procurement

A unique aspect of the project was the indirect manner in which equipment and supplies were procured for integration and assembly into the surveillance and ramp meter trailers. Procurement involved three agencies: Caltrans, UCI, and Hughes. Caltrans supplied UCI with funds and approval to procure items required by Hughes. UCI, in turn, subcontracted the actual trailer and communications systems development and integration to Hughes. Consequently, the trailers were the property of UCI and each piece of equipment had a "Property of UCI" inventory tag. The trailers will be registered in Caltrans' name once the contract with UCI is closed.

Several reasons have been offered as to why responsibility for procurement was originally assigned to UCI. One was to provide a system of checks and balances to ensure high value purchases. Another was to permit sole-source contracting to Hughes for trailer systems development and integration, a contracting mechanism that Caltrans is not permitted to offer. Still another reason was to further the Testbed partnership between Caltrans and UCI. Unfortunately, as it was implemented, the procurement process developed problems and was identified by several of the partners as a primary cause of major delays. 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.

2.4.1 Procurement Process

The contracts and subcontracts entered into by Caltrans, UCI, and Hughes specified a six-step procurement process. (1) Hughes was responsible for identifying the required equipment, securing at least three vendor bids for each item or set of items, and providing those bids and a recommendation to the TRT. (2) The TRT was responsible for approving the recommendation or requesting alternate bids. (3) Once Hughes received approval, a request for a purchase order was delivered to the UCI purchasing office, which then sent a copy to the Caltrans Contract Manager for approval. (4) When approved, Caltrans returned the request to UCI, who (5) then created a purchase order according to University of California procedures and standards. (6) The purchased items were shipped to the Hughes Receiving Dock or to the office of one of the Hughes team members, depending on relative size and value of the items.

2.4.2 Procurement-Caused Project Delays

Because of the complex nature of the procurement process, there were numerous opportunities for delay. For example, if the TRT spent weeks discussing the submitted vendor bids, the bids would expire before Hughes had an opportunity to request a purchase order from UCI. This required Hughes to secure other bids or forego an opportunity for reduced prices, contributing to project delays or creeping costs.
It is estimated that procurement difficulties delayed the project by many months. In many cases, the vendors either failed to deliver as promised, or were simply unable to supply the item in a timely manner. With no penalty provision in the contract, Hughes was unable to wield influence over delinquent vendors. While indirect procurement through UCI was found cumbersome, the FOT partners agreed that UCI handled procurement tasks with diligence. Allowing Hughes 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.

2.4.3 Modifications to the Procurement Process

Hughes, UCI, and Caltrans all agreed that a streamlined procurement process was required. A procurement procedure was preliminarily agreed to by the PMT members prior to the start of the systems integration portion of the FOT. The first Hughes Project Manager suggested that the Intelligent Power Controller (IPC) be purchased to test the process. A vendor bid was submitted to UCI in November 1994. A request for the IPC bids to be submitted to the TRT was made at a PMT meeting in February 1995. Not until early April did Caltrans give Hughes approval to request a purchase order from UCI. UCI then requested a quotation from Pulizzi Engineering, the chosen supplier. This quotation was received May 25 and the item was eventually received at Hughes in July of 1995. More than seven months was required to secure this item. Thus, it became clear than more streamlining was necessary.

After this experience, each individual involved in the procurement process agreed to give prompt attention to each assigned task. Still, there were serious delays. The Caltrans FOT Project Manager said in a July 13, 1996 memo to the second Hughes Program Manager, that he believed project slippage was "due to a failure to procure [equipment] in a timely manner," indicating that UCI and Hughes needed to communicate more clearly.

Better communication and delineation of responsibilities at the start of the project could have reduced or eliminated many of the problems. At the start of the project, Hughes believed that the UCI would negotiate with and select appropriate vendors. This misunderstanding led to problems and delays in purchasing items, until UCI made it clear that its function was solely to prepare purchase orders and that vendor negotiation was the responsibility of Hughes and Caltrans. Two reasons have been offered to explain UCI's limited involvement. One reason mentioned in an April 1997 telephone interview with UCI staff responsible for placing purchase orders is that the personnel assigned to this project did not have the technical expertise necessary to critically evaluate the bids and purchase orders. The second reason is that limited funding for purchase order support was provided to UCI. This reduced the priority assigned to the Hughes subcontract by the UCI purchasing office, which was also supporting several other projects.

Another factor that delayed the procurement process was the request for additional items after the purchase order was already processed. Two ways were found to deal with these requests: reprocess the purchase order or create a new purchase order following all the required procurement steps. Disputed items also caused delays, as did changes in scope and delays in other project areas. For example, a delay in executing the lease for the Union Bank building caused a delay in purchasing some items required for the relay site because Caltrans wanted to wait until the lease was finalized before purchasing this equipment.

UCI also noted during the April 1997 interview that University of California regulations required that all equipment purchased by UCI be inventoried and tagged, and that records of the purchases be maintained. However, because UCI had no storage area for the items and direct shipment to the Hughes Fullerton facility streamlined the procurement process, UCI never directly handled the procured items. Hughes assumed the responsibility for the tagging and inventory control. However, this was not a priority for Hughes who was trying to compensate for schedule delays. This caused problems with UCI's inventory records.

The property inventory tags were also an issue with Caltrans. Caltrans maintenance personnel are not permitted to transport or perform maintenance procedures on non-Caltrans vehicles. Exceptions were made to facilitate the FOT. Since the trailers belonged to UCI and not Caltrans during the FOT, storage by Caltrans became an issue. It was decided to store the trailers at Caltrans facilities whenever they were not in use. This required waiving Caltrans regulations that require all vehicles stored at Caltrans facilities to be registered in the Caltrans vehicle inventory.

2.5 Trailer Hitch Redesign and Replacement

The issues dealing with the trailer hitch design reveal the degree of cooperation that is necessary among the various departments concerned with the design, construction, and operation of the trailers. The design requirements for the surveillance trailers did not specify the type of trailer hitch. Mighty Movers, the company that constructed the trailers, attached a standard ball hitch to each trailer. It was later discovered that Caltrans uses a different type of hitch, the hook-and-pintel. This hitch is stronger than standard ball hitches and considerably more secure. The incompatibility between trailer and tow-truck hitches was identified when a Caltrans crew arrived at the Hughes Fullerton facility to transport one of the trailers. The crew was not able to attach their tow vehicle to the trailer. Mighty Movers was contacted to redesign and replace all trailer hitches.

Another issue concerned the relative heights of the hitches on the tow vehicles and trailers. As the final gross weight of the trailers was greater than expected, heavier trucks were needed to tow the trailers. The required trucks were easily located in the Caltrans inventory of tow vehicles. However, when the trailers were mated with the heavier tow truck, a height differential was discovered between the trailer and tow-truck sections of the hitch. Because the tow truck was higher than the trailer, the rear of the trailer was lowered when attached to the truck and, consequently, had insufficient ground clearance. Mighty Movers was again contacted to provide replacement hitches. The final hitch is a height-adjustable hook-and-pintel hitch that is compatible with all Caltrans tow vehicles.

Caltrans has investigated contracting the trailer towing operation. It is unknown whether the need for hook-and-pintel hitches has been addressed with outside contractors.

2.6 Portable Power Generation System

Several issues concerning the liquid propane gas (LPG) generators and battery power system arose. These included operating time between refueling, operating from external commercial AC power, generator fuel selection, battery recharging and maintenance, and photovoltaic charging systems.

2.6.1 Expected versus Actual Operating Time between Generator Refueling

The surveillance trailers required refueling approximately once per month during trailer assembly and systems integration according to Hughes. Refueling rates experienced during the FOT evaluation were obtained later from the trailer logs as part of the I-5 Test. Caltrans expected the average time between refueling to be about 10 to 14 days when the trailers were deployed and operating in automatic mode. This refueling interval is acceptable to Caltrans for operational trailers, although it would be preferable to refuel less often. At first, refueling the trailers required the attendance of Caltrans personnel to unlock the trailer and supervise the operation. With experience, it was found that the trailer door to the LPG tank could be unlocked the day before the refueling occurred or at an appropriate time when Caltrans personnel were available.

In order to allow volume for propane gas to safely accumulate, the liquid propane tanks on the trailers can only be filled to 75 percent of their maximum capacity. Thus, surveillance trailers can hold 88 gallons of liquid propane and ramp meter trailers 33 gallons. Since the tanks cannot be filled to maximum capacity with liquid propane, the refueling frequency is increased.

Another factor that increased refueling frequency is the demand the electronic components place on generator-produced power. In the original surveillance trailer design, the 170 controller, wide area communications controller, and the 64 Kbps spread spectrum backbone radio were operated with AC power from a battery-driven inverter. All other surveillance trailer systems, including the AutoScope VIP; cameras; pan, tilt, and zoom controls; video compression system; and high bandwidth spread spectrum radios that support video transmission operated directly from AC generator power. The large AC generator power requirement caused the generator to turn on frequently. Conversations with the Hughes Project Manager indicated that a different design, in which all surveillance equipment operates on inverter AC power supplied by batteries, might be preferred. This alternate design utilized a larger battery/AC inverter system that required the generator to operate only when the batteries required charging. Further analysis was conducted to determine the effectiveness of this potential design change. Upon the completion of the FOT, all the surveillance trailers were returned to the trailer manufacturer for installation of the new AC inverter power system as discussed further in Section 2.6.4.

Surveillance trailer refueling was also affected by the increase in scope placed on the trailer systems during the development cycle. The trailers were initially designed to support ramp metering only, but scope creep increased the trailer requirements to allow remote viewing of imagery, remote switching and controlling of surveillance cameras, and the addition of a security camera. This increase in operational capability increased the demands on the battery and generator system, preventing it from operating for as long as desired between refueling.

2.6.2 Operation with Externally Supplied AC Power

The mobile surveillance trailers can operate from externally supplied AC power (i.e., public utility commercial power). The trailers are equipped with a transfer relay, allowing them to be safely switched between generator and external AC power. In fact, Hughes operated the trailers from externally supplied AC power during their development with no technical difficulties. The trailers were not operated from external AC power (with the exception of one trailer in the I-5 Test) during the FOT for two reasons: (1) the partners wanted to test the ruggedness and reliability of the portable power generation system and (2) Caltrans maintenance personnel were not available to provide AC service at all evaluation sites.

When deployed for the FOT, trailer operation from external AC power required Caltrans to install a rugged power cable for outdoor use and devise a locking mechanism for the AC outlet or power source. Hughes offered to assist Caltrans in safely making the connection to external AC power. In fact during the I-5 Test, the surveillance trailer at

Culver Drive was satisfactorily operated from commercial power and experienced less power system problems than any of the other trailers.

2.6.3 Selection of Propane as the Generator Fuel

Propane generators were selected for the mobile surveillance trailers for the following four reasons:

1. Caltrans stated from the beginning of the project that they would utilize a contractor for refueling. Therefore, the need for special refueling equipment was not an issue.

2. Propane is safe to refuel.

3. Gasoline is extremely volatile, especially during hot weather, and presents significant safety hazards making it not desirable.

4. Diesel generators would generate visible and potentially harmful exhaust.

Hughes believed that diesel generators would probably provide more reliable operation and be suitable for the trailers. Most of the reliability problems with the propane generators were attributed to deficiencies with the analog generator control circuitry. This control circuit and its associated problems are described in the next section.

2.6.4 Charging and Maintenance of Batteries

The technical problems with the mobile surveillance and ramp meter trailer generator and battery systems can be traced to the original analog control system that regulated battery charging and the purchase of oversized generators. The technical problems included battery failure and generator starter maintenance. The Hughes engineering staff attributes the battery and generator starter problems to over discharging the batteries and commanding the generator to start while it was already running. The analog control system monitored the battery charging voltage and received generator start and stop requests from the wide area communications controller in the form of relay closures. The battery had to be charged to its maximum voltage before the generator turned off at the end of a charge cycle.

Battery Charging Control System - The primary deficiency of the analog control system was that it did not provide repeatable turn-on and turn-off of the generator at precise battery voltage levels, i.e., at predetermined thresholds to optimally maintain battery charge. Another problem with the analog control system was that it could not sense if the generator was on, allowing the generator starter to be engaged while the generator was already running.

The analog control system was replaced with a microprocessor-based system that corrected the lack of repeatability in generator control. The new microprocessor-based system utilizes two analog-to-digital (A/D) inputs to monitor battery charging voltage and generator-on status. The microprocessor-based system provides precise generator start and stop control based on the battery charging voltage reaching programmed start and stop thresholds. It can time-average the battery voltage and ensure that generator start and stop commands are not affected by short-time duration transients in battery voltage. The system also provides a serial port for monitoring the wind speed indicator and solenoid outputs for controlling automatic mast retraction.

The microprocessor-based power control system appears to have corrected most of the battery charging system problems. Tests show that the generator start and stop battery voltage thresholds can now be adjusted to maintain optimal battery charge in the surveillance and ramp meter trailers. The surveillance and ramp meter trailers require different generator start and stop battery voltage thresholds because different loads are driven by their batteries. Hughes has recommended that Caltrans follow the maintenance procedures specified by the battery manufacturers.

Oversized Generators – The generators purchased for the surveillance trailers were oversized for their intended use, running at about 10 to 15 percent of full capacity. This type of generator operates best, however, at a 50 to 80 percent load. Since the generators were not loaded properly, the piston rings were never seated properly and glazing and carbon buildup occurred. This led to excess oil use. When the oil was low, a protective feature prevented the generator from starting. However, this protective mechanism did not function properly and further contributed to starting problems. It was later determined that isolating the battery that started the generator from the battery that powered the electronic equipment would have allowed better charging protocols to be designed. These problems were later corrected when a new power management and distribution system was designed and installed in the surveillance trailers.

Further enhancements to the battery charging system were recommended by Hughes. They included full disconnect of the DC power system from the battery if the microprocessor-based power control system failed to start the generator during normal operation. The DC power disconnect was designed to prevent the batteries from fully discharging if the generator failed to start and did not charge the batteries as needed.

At the conclusion of the FOT, the portable power generation system for the surveillance trailers was redesigned and a new power system was installed in the six surveillance trailers. The redesign included installation of two 12-volt batteries, reallocation of the equipment powered directly from batteries and directly from the generator, an improved generator auto start control, automatic disconnect of the DC power system, and improved access to the batteries by placing them under the roof hatch access structure inside the trailer.

2.6.5 Photovoltaic Charging Systems

The mobile surveillance and ramp meter trailers do not currently utilize photovoltaic cells to recharge the batteries in the surveillance trailer. Hughes estimated that it would cost approximately $12,000 per surveillance trailer for a photovoltaic charging system. Caltrans indicated that solar operation of the trailers would not be desirable at this cost. One alternative to full solar operation is to power the security system with solar power. This would allow the security system to remain operational regardless of the charging state of the primary batteries.

Operation of the ramp meter trailers from solar power would be less costly because of reduced power requirements. The primary obstacle to using solar power to charge the ramp meter trailer primary battery is lack of a protected location for the photovoltaic panels.

Both the meter-on sign and the remote signal head that are part of the ramp-metering system do utilize solar power to supplement power supplied by the generator. The solar powered subsystems operated satisfactorily during the FOT. Hughes predicts that these components will run for approximately ten simultaneous cloudy days without a recharge. Their extended operation under solar-only power has not been field-tested.

2.7 Automatic Mast Retraction

In order to accommodate the installation specifications for the VIP and SSR equipment on the surveillance trailers, each was equipped with a retractable mast. The pneumatic mast selected for this application is capable of repeatedly lifting the cameras, their enclosures, and communications antennas. It is compatible with the other equipment contained within the trailers, does not require excessive modification to the trailer's structure, and had previously been used by Hughes with acceptable results.

When the mast is fully extended, the cameras are positioned approximately 32 feet (9.8 meters) above ground level. Econolite specifies this height as the minimum acceptable for roadside video image processing. Evidence of this was demonstrated by the difficulties encountered when Caltrans attempted to operate the surveillance trailers with the masts at less than full extension. Because the trailers sit at the side of a road, the cameras must be as high as possible to minimize shadowing of smaller vehicles by large trucks and the projection of the image from tall vehicles into adjacent lanes. The greater the camera height, the more accurate are the measured traffic flow parameters. Some permanent side-viewing VIP installations use cameras mounted at 60-feet (18.3-meter) heights. When the camera can be mounted over the middle of the monitored lanes, more accurate values of traffic volume, lane occupancy, and vehicle speed can be measured than from the side-viewing geometry (even with lower camera mounting heights).

Although Caltrans indicated that they would prefer a taller mast, attaining the current 32-foot (9.8-meter) height presented challenges. Outriggers were required to protect the trailers against tipping before the mast could be installed. The mast also needed to be stable during strong wind gusts to provide a stable platform for the VIP cameras. Too much movement in the mast would cause the image processor to lose calibration. Mighty Movers reinforced the floor of each trailer with thicker steel plates. This provided additional strength for the mast's mounts and ballast to the trailer.

Still, Caltrans was concerned that strong winds would cause the trailer to tip over or the mast to break. Caltrans requested that the masts be modified to retract automatically whenever strong winds are present. In response, Hughes ordered the necessary modification. The tops of the masts were equipped with wind-speed measurement sensors. When winds reach 70 mi/h (112.7 km/h), a relay is activated to open solenoid valves on the top three sections of the mast, retracting it into a safe position. Only the top three sections are lowered to avoid damaging the SSR antenna that transmits video and data to the relay site. This antenna has to be turned and reoriented manually before full mast retraction can occur.

The automatic mast retraction requirement was added after the initial design specification was released. This modification caused significant delays and presented serious technical and logistical challenges. As of June 30, 1997 (after the Anaheim Special Event Test was completed), the automatic mast retraction feature remained inoperable, delaying the Systems Acceptance Test. By the time the I-5 Test began in Spring 1998, automatic mast retraction had been installed and tested. Some of the FOT partners believe the 70-

mi/h (112.7-km/h) wind requirement placed an undue burden on the design. Others believe the wind requirement could have been met without automatic mast retraction.

Those who argue against automatic mast retraction point out that the trailers are being developed under a field operational test for testing a concept and are not intended to serve as permanent equipment. As such, it is appropriate to emphasize design and cost containment. Caltrans, on the other hand, was concerned about safety. This was a serious liability concern for Caltrans given that in recent years, two large overhead freeway signs had been brought down by wind and one resulted in the death of a motorist.

Those who argue against automatic mast retraction point out that the trailer structure is sufficient to protect against trailer tip over in strong wind. Furthermore, the mast structure is adequate to protect it from snapping. The worst case scenario is that a strong wind may cause the upper segment of the mast to break off, causing it to swing down and hang by the attached cables. These arguments, however, were formulated only after the trailers were delivered and team members had a chance to work with the trailers. Prior to trailer delivery, much was unknown about the strength of the trailer components. As such, many team members were motivated to take extra precautions.

2.8 Caltrans TMC System Integration

System integration issues included surveillance trailer and camera selection using the Automated Traffic Management System (ATMS) TMC software and display of trailer data on the TMC workstations.

2.8.1 Camera Selection Using the TMC Freeway Management Software

The freeway management software developed for the Caltrans District 12 TMC by National Engineering Technology (NET) did not exist when the Mobile Surveillance and Wireless Communications FOT Project was started. The remote-site user interface planned when the FOT was first initiated was PC based. The decision to increase the capabilities of the mobile surveillance trailers to include video image switching and camera control using the workstation-based TMC software significantly changed the scope of the software project and added new integration issues not previously planned. Additionally, some trailer control functionality was lost because of the integration of controls into the freeway management software, including the ability to monitor battery voltage. The camera control issues and their resolution are described below.

NET controlled the mobile surveillance trailer cameras with the freeway traffic management software by generating camera control commands transmitted through a terminal server. Hughes camera control software then passively listened to the commands and performed the camera movements without providing feedback to the TMC software. The primary problem encountered during the integration of the camera controls into the freeway management software was that NET could not reliably send camera control instructions from their terminal server to the Hughes interface. To support camera control and system troubleshooting, Hughes wrote a diagnostic program that showed when the Hughes software was receiving instructions from the TMC software. The diagnostic program allowed operators to determine if a surveillance trailer camera control problem was due to TMC software not providing the commands to the Hughes software, or due to Hughes software not receiving the commands and correctly transmitting them to the surveillance trailer. NET solved most of their terminal server problems within a few days. Caltrans and Hughes agree that this part of the integration is complete.

An additional video integration issue was related to the video switch in the TMC. This switch, which is not full-matrix but a tiered switch, requires surveillance video to enter the TMC on a single input. This use of a tiered switch, combined with the TMC database design, means that the TMC can view only one trailer video source at a time. Additional issues pertaining to video switching and control limitations encountered at the District 12 TMC, Anaheim TMC, UCI-ITS Laboratory are discussed in Section 2.10.

The final surveillance trailer camera integration problem relates to updating the District 12 TMC device database when a surveillance trailer is moved. Personnel at the TMC must modify the database to reflect the new trailer location and then restart the application software. If a new trailer icon is created, TMC software communication processes must also be restarted. If the database is not updated, the trailer icon on the workstation map will 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 map will eventually become cluttered with icons representing nonexistent trailer locations.

Hughes and Caltrans believe that the system integration issues relating to display and control of camera video from the NET software are complete and have been resolved satisfactorily. Caltrans has stated that although the camera switching and controls are not optimal, they do perform according to the design specifications. Some care is needed in selecting cameras on a trailer using the icons at the workstation because the individual icons are closely spaced.

2.8.2 Integration of 170-Controller Data with Front End Processor

One of the issues affecting the integration of the 170-controller data in the surveillance trailers with the TMC Front End Processor (FEP) was the delay imposed by the communications backbone data transfer protocol. This delay caused the FEP to timeout while waiting for polled data to arrive from the surveillance trailer. The problem is that the surveillance trailer wireless backbone can not guarantee a response to polls from the FEP within the required 100 milliseconds. To resolve the timeout problem, the Hughes software continuously collects170 data received over the wireless SSR communications backbone and stores it locally within the TMC. The locally stored data are then retransmitted to the FEP within the required 100 milliseconds of being polled. The temporary storage of the 170-contoller data causes the FEP to receive data that is about 30 seconds old. The 30-second latency does not appear to have a negative effect on system operation due to the general slowness of the TMC software in displaying the 170-controller data on the graphical user interface at the TMC workstations.

If desired, the age of the 170 data supplied to the FEP from the mobile surveillance trailers can be decreased by upgrading the priority of the communications packets containing FEP polls and their responses over the wireless backbone. The reduction in 170 data packet response time would come at the expense of reduced responsiveness of the camera control system, which is not desirable.

2.9 Data Capture and Presentation

Each surveillance trailer is equipped with an AutoScope 2004 VIP whose outputs emulate inductive loop data. The VIP analyzes traffic video imagery to generate traffic data such as vehicle count, lane occupancy, and vehicle speed. Much discussion during the FOT dealt with interpreting and utilizing the emulated loop output data. The ability of the AutoScope to interface with the 170 controller and thereby potentially control ramp metering has been demonstrated as part of the FOT.

As of the conclusion of the FOT, the polled 170-controller data from the surveillance trailers had not been integrated with the District 12 TMC software such that they were displayed on a workstation graphical user interface. 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. Discussions were held with the ATMS software contractor and with Hughes concerning these issues.

Remedies were attempted, but the VIP data could not be accessed from the ATMS 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).

Only the District 12 TMC has purchased an AutoScope supervisory computer. Therefore, they are the only agency that can configure AutoScope detection zones and access the VIP traffic volume, lane occupancy, and vehicle speed data. For the Anaheim TMC or the UCI-ITS Laboratory to acquire VIP data from the trailers, they would need to purchase an AutoScope supervisory computer or some other hardware/software combination capable of displaying the loop-emulated outputs produced by the VIP. Neither agency has an immediate need to view these traffic data.
Anaheim has found it prohibitively expensive to perform the software modifications necessary to integrate the VIP trailer data into their traffic management system and has decided not to purchase the supervisory computer. However, UCI-ITS laboratory will eventually be able to receive surveillance trailer data over the fiber optics backbone that connects it to Caltrans TMCs.

Hughes was to provide three data loggers to record the emulated loop data and other data. The data loggers were to output a stream of comma-delimited text corresponding to the recorded sensor data or other information input to the data logger (such as "vehicle presence" or "communication packet dropped"). The comma-delimited format presents a minor problem for researchers seeking readily available PC-formatted traffic statistics, such as vehicle-by-vehicle detections or a series of five-minute vehicle counts or five-minute average vehicle speeds. A plan for resolving some of these issues was proposed, e.g., performing relatively simple data averaging in real time and recording the results on the data logger, and using commercially available software to strip out the data fields. However, these procedures and satisfactory data logger operation were not demonstrated during the FOT.

2.10 Shared Camera Selection and Control Among Agencies

An objective of the wide-area wireless communications network was to allow the Caltrans District 12 TMC, Anaheim TMC, and UCI-ITS Laboratory to share remote control and access to video and data transmitted from a surveillance trailer. This would provide TMC operators and researchers real-time traffic flow information that might otherwise be available at only one facility.

With the original design of the video switching and camera control system, only the District 12 TMC had full, autonomous control of the system. The Anaheim TMC would contact the District 12 TMC by telephone to request a particular camera image or to move a camera left, right, up, down, or have the lens zoomed. Midway through the project, this arrangement was deemed unsatisfactory to Anaheim TMC personnel in planning for their key role in the Anaheim Special Event Test. In response, Caltrans asked Hughes to upgrade the video switching and camera control capabilities at the Anaheim TMC. The UCI-ITS Laboratory remains without autonomous video switching and camera control.

2.11 Relay Site

Wireless communications to and from the mobile surveillance trailers are limited to line-of-sight distances. Therefore, it was necessary to locate and build a relay site to retransmit video and data from the trailers to the TMCs and UCI-ITS Laboratory. Video and data reception were also required at the Hughes Fullerton facility during trailer systems integration as shown in Figure 2-1. In addition to being in the line-of-sight of the trailers, the relay location had to be free from interference from electronic noise and blockage by fixed objects, such as buildings and trees, that attenuate signals.

Figure 2-1. Trailer assembly at Hughes in Fullerton, CA showing ramp trailers and signal heads in foreground and surveillance trailers in background

2.11.1 Relay Site Selection

Several potential locations were identified for the relay site, including a local radio station tower, the rooftop of the Union Bank building, and the summit at Santiago Peak in central Orange County. Santiago Peak, because of its 5670-foot (1728-meter) elevation, could provide a significantly wider area of coverage than the other locations. However, the unimproved road leading to Santiago Peak created installation and maintenance difficulties and increased expense. Furthermore, the reduction in the scope of the FOT relaxed the requirement for wide-area coverage extending into southern Orange County. The local radio station tower option was also rejected because of potential interference and the prohibitively high rent expense. Following extensive line-of-sight and signal-strength testing, the rooftop of the Union Bank building in Santa Ana was selected as the relay site location.

2.11.2 Lease Agreement

UCI negotiated a lease agreement with the Segerstrom Office Center, the owner of the Union Bank building. The terms of the lease set the monthly rent and stipulated several other conditions that ultimately increased the overall cost of the relay site. One condition was to modify the rooftop by creating walkways constructed of resilient materials. Furthermore, liability and fire insurance policies providing one million dollars of coverage needed to be purchased. Lastly, the installation of valuable communications equipment on the roof of the building could potentially increase the building's market value, as assessed by the local tax authority. The terms of the lease agreement dictated that any increase in annual property taxes caused by the additional equipment would be the financial responsibility of UCI. The relay site selection process, culminating in a lease, was a time consuming task taking fifteen months to complete.

2.11.3 Relations with Union Bank Building Management

The Union Bank relay site has worked exceptionally well according to the Hughes Project Manager. This site, which had some anticipated access problems, has been easy to use and much less expensive than the other alternatives. The building's managers have been accommodating in providing rooftop access to Hughes and Caltrans technical personnel, even on weekends. The building's managers have also provided advance warning to Hughes prior to scheduled power outages. Power outages and power "spikes" within the Union Bank building can cause technical problems at the relay site. Fortunately, unplanned power disruptions for which advance warning cannot be given are infrequent.

2.11.4 Coverage Area

The antenna on top of the Union Bank building has met its objective of supporting wireless communications. Hughes is extremely pleased with the performance of the 270-degree sector coverage of the antenna. The antenna provides a 23-dB path margin for communications at the 5-mile (8.0-km) boundary. Even communications between the relay site and trailers parked at the Hughes facility 8.5 miles (13.7 km) away have been reliable during system development. Hughes has stated that they have not yet situated a trailer within the specified five-mile (8.0-km) line-of-sight operational radius that could not be supported. The worst case encountered was the surveillance trailer location near the First Street onramp to I-5. Obstructions that at first hindered line-of-sight communications to the Union Bank relay site were alleviated by moving the trailer a couple of hundred feet from its initial location.

2.11.5 Proposals for Increasing Deployment Range

During the FOT, trailer deployment was limited to locations that were within range of the relay site on top of the Union Bank building in Santa Ana, CA. The relay site permitted wireless communication within a five-mile (8-km) radius as long as the line-of-sight to the surveillance trailer was unobstructed. This range was adequate for planned FOT activities.

Several meetings of the PMT were held to discuss five options for extending the effective range of the trailers that were presented by Hughes. These were the construction of a new retransmission site on the top of Santiago peak in Orange County, a series of relay sites along the I-5 and SR-91 corridors linked with SSRs, a combination of the Santiago

Peak and local relay site approaches, integration of local relay sites with existing fiber optics lines, and use of RF amplifiers to propagate signals along the relay path. At present, no action has been taken to implement any of the alternatives.

2.12 Trailer Security

Since the equipment located within each of the surveillance trailers is valuable, the need for adequate security became apparent. The chosen security system is cellular-based. Alternative designs that were considered include a radio-based system and a private security service. The radio-based system was rejected because it provided a smaller area of coverage and offered no cost savings. The use of a private security service was also rejected because of cost.

Security system intrusion sensors are located on the surveillance trailers and the ramp meter trailers. Other parts of the security system, located in the surveillance trailer, include a wireless receiver, a control panel/communicator, and a cellular telephone interface transmitter. The wireless receiver accepts status notifications, such as "ramp meter trailer fuel low", and security alert signals that warn of a potential intruder. The wireless receiver passes these signals through the control panel/ communicator to the cellular telephone interface transmitter and on to the cellular telephone network. The receiver at the District 12 TMC is "dialed up" by the cellular telephone network to deliver status notifications and security alerts.

The surveillance trailer also contains a fixed-position black-and-white camera from which TMC staff can view activity at the door to the trailer and a loud-sounding alarm that is triggered upon trailer break-in. Adding the fixed-position camera represented a change in scope in the security system design that was initiated mid-way through its implementation. Once the TRT determined that a security surveillance camera was needed, and the option of relying on the pan, tilt, zoom (PTZ) mast-mounted color camera for security was rejected, it was decided that a fourth camera would be added to each surveillance trailer. The TRT reasoned that the PTZ mast-mounted color camera would normally be monitoring traffic flow and would, therefore, not be available for security surveillance.

One area of the TMC has been designated as the trailer security and system monitoring station. It contains a workstation, telephones, and dot matrix printer that are monitored by District 12 and CHP personnel. Each time the security system delivers a signal to the TMC, an "attention" tone is sounded and the corresponding output is produced at the printer. Standard operating procedure requires that a TMC operator go over to the security station, read the output, and determine whether a security alert has been received. If the TMC operator finds the output to be a low priority status notification, no action is taken. If the TMC operator finds the output to be a high-priority security alert, the operator requests that a CHP officer be dispatched to the trailer.

The graphical user interface (GUI) at the security workstation provides the following information:

1. Date
2. Time
3. Battery voltage in both the surveillance and ramp meter trailers
4. High and low voltage settings that control generator turnon and turnoff

5. Outside and inside temperatures at a surveillance trailer
6. LED status that shows the state of the generator/battery system
   - Yellow to indicate voltage is within the preset high/low range
   - Yellow flashing to indicate the generator is on
   - Red to indicate the voltage is below the low-voltage threshold
   - Red flashing to indicate the generator tried to start three times and failed
   - Green to indicate the voltage is above the high-voltage threshold
   - Green flashing to indicate the generator is on and charging the battery
7. Historical data in five-minute intervals from a saved database file
8. Alarms that indicate a system malfunction.

Operating the security system presented challenges early in the project. For instance, one trailer at a freeway onramp sustained minor damage because of an attempted break-in that went undetected. Additionally, early communication between project staff and the CHP was incomplete. Consequently, officers were uncertain as to their responsibility when responding to trailer security alarms. Furthermore, it was found they did not know the exact location of each surveillance trailer.

Perhaps the most serious problem identified in conjunction with the security system was the procedure by which the TMC operators were detecting and responding to potential break-ins in Spring 1997. During these months, the TMC "attention" tone would sound dozens of times each day. Initially, a member of the TMC staff would go over to the security station and investigate the cause of each tone. Finding each case to be one of a status notification that required no immediate action, rather than an intruder-initiated security alarm, the TMC staff eventually lost interest and stopped checking the security system output. This is a classic case of "The Boy who Cried Wolf." The alarm is no longer sounded for a status notification.

Two other issues were identified. The first was that at least one TMC operator does not hear the TMC "attention" tone when it is sounded. The particular pitch used by the system is within a range of tones that are undetectable by persons with hearing difficulties. Therefore, a visual indicator was installed. The second is that the output produced by the printer is encoded. As such, it cannot be interpreted without the assistance of a separate sheet of paper that explains what each code means. Such a paper is now taped to the printer or left nearby in a clear protective folder.

2.13 Technical Training

Another aspect of the FOT was the technical training provided by Hughes for the benefit of Caltrans maintenance and engineering personnel responsible for trailer operations. Specific training dates were agreed to by the PMT based upon the project schedule provided by Hughes. Formal training on the AutoScope VIP was held the first week of October 1996. Econolite delivered this training at their facility in Anaheim, CA. In attendance were three Caltrans maintenance and engineering personnel, the Caltrans New Technology project manager, and representatives from both Hughes and the Evaluation Team. The training was held simultaneously with a tour of an incomplete surveillance trailer at the Econolite facilities. Originally scheduled to coincide with trailer deployment and System Acceptance Test (SAT) activities, this training session was completed eight months prior to deployment and SAT because of project delays. Consequently, refresher training was necessary.

Some uncertainty existed as to what training was to be provided by Hughes. The contract required eight hours of formal maintenance training and no less than twelve hours of on-the-job (OTJ) operations training. Midway through systems integration, the Hughes project manager indicated that he believed Caltrans had received the specified number of OTJ training hours. Caltrans disagreed, indicating that the lead Caltrans engineer had not had demonstrations of all the systems. The engineer's familiarity with the trailers gained through his close working relationship with the Hughes personnel who assembled the trailers was not adequate preparation for him to train other Caltrans personnel. Hughes refused to provide operations training beyond the experience the Caltrans engineer received from working on the trailers.

Hughes personnel, however, did demonstrate the care and handling of the surveillance trailers during a half-day training seminar at the Hughes Fullerton site on the same day the AutoScope training occurred at Econolite. This included a demonstration of hitching the trailer, lowering and raising the stabilizer legs and retractable mast, starting and shutting down the generator, and replacing the oil and battery fluids. The training did not include a demonstration of ramp meter trailer use because the trailers were not completed at the time. It was understood that this training did not adequately cover the safe handling of propane. In a personal interview in January 1997 with the lead Caltrans engineer, he indicated that the special requirements of handling propane-filled generators were not taken into consideration when structuring training sessions and stated this item should have been included, since no other Caltrans equipment utilizes propane as its primary fuel.

Most of the training requirements were fulfilled through OTJ training that allowed Caltrans personnel to observe and ask questions during initial trailer setup and test. Although some maintenance personnel indicated that they would have appreciated being trained prior to their initial contact with the equipment, OTJ training may have been the second most effective and cost-beneficial method of providing adequate training in terms of minimizing the number of person-hours required.

Caltrans District 12 TMC operators required an informal training session to learn how to pan, tilt, and zoom the cameras, switch between cameras, and remotely turn the trailers on and off. Again because of project delays, the TMC training demonstration was conducted many months before TMC operators were able to utilize these features. As result, most operators had forgotten everything from the demonstration and had to relearn the procedures through OTJ.

Anaheim declined participation in the full series of planned training activities because they could not afford the staff time. Anaheim TMC personnel received a demonstration of the trailer and camera control interface keyboard on the night of the initial deployment for test activities. This consisted of a Hughes representative demonstrating all the features of the software interface and allowing the Anaheim operator time to practice and ask questions regarding the procedures. An instruction guide was prepared and provided to the Anaheim TMC operator. This training was found to be adequate and beneficial because of the ease of use of the keyboard and because it was quickly reinforced through experience during operation of the trailers that evening.

2.14 Trailer Transport and Setup

Issues related to trailer transport and setup were addressed at different stages of the project and were evaluated in both the Anaheim Special Event and I-5 Tests. As such, most aspects of this activity are contained in other sections. The issues identified below were uncovered outside of the specific Anaheim Special Event and I-5 Tests during meetings and system testing.

1. When loading the trailers, beware of gross weight limitations. The ramp meter trailers exceeded the legal weight limit when the stabilizing plates were added.

2. When towing the trailers, beware of low hanging tree branches and other height obstructions. The whip antenna atop a trailer was damaged during one transport event.

3. Position the trailer with the door facing the freeway. It is believed that such positioning would have prevented an attempted trailer break-in.

4. Locate the trailer away from ant hills, if possible. Ants are attracted to the warmth of the equipment. They can eat wire insulation and cause electrical short circuits.

5. Position the trailer and rotate the mast such that the antenna will not block the camera from viewing desired traffic flow patterns.

2.15 Ramp Meter Trailer Design

The items identified in this section were noted during preliminary testing of the ramp meter trailers before the I-5 Test was begun.

1. Each ramp meter trailer is paired with a particular surveillance trailer. A given ramp meter trailer cannot be made to work with any other surveillance trailer without reprogramming the SSRs.

2. Initially attached to each signal head was a sign that read either "One Car Per Green" or "Two Cars Per Green.” As all ramps in the FOT were programmed for "One Car Per Green", some signs had to be replaced. In future day-to-day operations upon completion of the FOT, spare signs should be stored on the ramp trailers to accommodate both metering configurations.

3. Onramps with metering signals on both sides of the ramp require that the two signals be synchronized. This task is performed by the control data sent by the surveillance trailer to the ramp meter trailer.

2.16 Equipment Costs

The equipment costs for the surveillance and ramp meter trailers, Caltrans District 12 TMC, Anaheim TMC, ITS laboratory at UCI, and the relay site are shown in Tables 2-1 through 2-6. Table 2-7 summarizes the costs for the equipment listed in the first six tables. Prices for some equipment, such as the security system telephones and security alarm receiver and printer located in the Caltrans District 12 TMC, were not available. The cost for the winch and hydraulic crane that were used to service the generators is shown on the District 12 TMC equipment list, although it is a service item. Figure 2-2 illustrates the relative contributions of the six surveillance trailers, three ramp meter trailers, District 12 and Anaheim TMCs, UCI-ITS Laboratory, and the relay site to the total equipment expenditure. The six surveillance trailers represent 70 percent ($749,778) of the total equipment cost, the three ramp meter trailers 16 percent ($171,540), the District 12 TMC 5 percent ($50,552), the Anaheim TMC 2 percent ($23,654), the UCI-ITS Laboratory 2 percent ($24,399), and the relay site 5 percent ($57,109). One surveillance trailer and its associated equipment therefore cost approximately $125,000 and one ramp meter trailer and its equipment approximately $57,000.

Table 2-1. Surveillance trailer equipment

Surveillance Trailer	Item	Price
Trailer Body	Mighty Mover Model 6.5NHMFA26115C Includes generator, LPG tank, charger, batteries, compressor, telescoping mast, air conditioner, stabilizers, equipment racks, hitch modifications	$48,403
Equipment	Wide Area Communications Controller	$6,750
	Intelligent Power Controller, Pulizzi IPC 3102-2157	$1,074
	Global Positioning System Receiver/Antenna, Trimble Pacer 400	$645
	Cellular Security System with 2-Way Voice	$5,667
	Spread Spectrum Radio (SSR) Components	
	192 Kbps SSR, Cylink ALM19E-00AE	$2,795
	256 Kbps SSR, Cylink NSPALS256EIA-530	$4,495
	64Kbps SSR, Cylink LASM6405 AE EIA-530	$2,995
	2-way RF Power Splitter/Combiner, Cylink ZAPD-4-N	$120
	Burst Synch Cable 1398-1010	$50
	Yagi Antenna, Cushcraft Signals PC904N	$40
	Semi-Parabolic Antenna, Cylink 0870-0031	$110
	Analog 8 Channel Radio, Linear MR168R	$149
	NTSC Video Monitor, JVC 14" TM-131SU	$330
	Keyboard, PC, Mitsumi KPQ-E99ZC-13	$35
	Pan and Tilt Assembly American Dynamics AD1236/24 (qty 4)	$3,183
	Receiver/Driver for the Pan Tilt Zoom, American Dynamics AD1641S-2 (qty 4)	$1,852
	Video Distribution Amplifier, American Dynamics AA-AD1421 (qty 4)	$820
	Video Patch Panel, Anixter Catalogue 102387	$206
	Video Switcher Unit, American Dynamics AD 1404A	$690
	Camera Control Keyboard, American Dynamics Model 1676B	$499
	Video Encoder, Enerdyne ENC2000R2	$6,912
	Video Image Processor, Econolite Autoscope 2004P1C-1M1-V2-RM	$18,320
	Autoscope B&W Cameras-16, 25mm lenses (Cohu) (qty 2)	$4,741
	Color Camera with Motorized 8-80mm Zoom Lens (Pelco PCHC4602)	$1,726
	Security B&W Camera (Burle TC355AC)	$328
	Color Surveillance Camera Environmental Enclosure Pelco EH4722-2	$250
	Burle Camera Enclosures w/Heater, Fan, Burle TC9383-2 (qty 3)	$561
	170E Traffic Controller	$850
	Generator Auto Start Panel and Electronics	$1,056
	Weather Station, Peet Brothers Ultimeter 500	$239
	Wind Monitor YG66810OS744	$744
	Power Transformer/Circuit Breaker	$40
	Electromechanical Relay Board, Computer Boards CIO-ERB24	$189
Miscellaneous	Diodes, Coil, & Various Electronics	$840
	Solenoid Air Valve	$900
	Coils, Sockets	$123
	Junior Gage Head Kit (for LPG fuel level monitoring)	$894
	Circuit Breakers	$201
	DC-DC Solid State Power Converters	$105
	Cables	$783
	Plugs, Clamps, Guide Pins	$552
	Items #82 (Cables)	$1,733
	Items #89 (Cables)	$1,568
	Connectors	$100
	9-18VDC Power Supply	$300
	Total	**$124,963**

Table 2-2. Ramp meter trailer equipment

Ramp Meter Trailer	Item	Price
Trailer Body	Flex-O-Lite TRFC Model 2001 Special. Includes generator, LPG tank, charger, battery, signals, cables, solar panels, signal and meter on sign supports, tool chest, hitch modifications	$40,334
Equipment	Wide Area Communications Controller	$6,750
	Analog 1 Channel Radio, Linear MR161T	$123
	Analog 8 Channel Radio, Linear MR168T	$141
	Analog 1 Channel Radio, Linear MR161R	$123
	Intelligent Power Controller, Pulizzi IPC 3102-2157	$1,074
	Generator Auto-Start Panel	$1,056
	Programmable Tiny Drive Controller	$169
	Spread Spectrum Radio (SSR) Components:	
	19.2 Kbps SSR, Cylink ALM19E-00AE	$2,795
	Digital SSR, Digital Wireless WIT 915 (qty 2)	$1,976
	Yagi Antenna, Cushcraft/Signals PC904N	$40
Signal Lights	Signal Lights - Halogen (qty 2)	$34
	Signal Lights LED (Red 8", 12" 2 each; Amber 8" 4 each)	$2,067
Miscellaneous	Junior Gage Head Kit	$149
	Diodes, coil, & various electronics	$140
	Cables	$130
	Padlock (qty 4)	$44
	DC-DC Solid State Power Converter	$35
	Total	**$57,180**

Table 2-3. Caltrans District 12 equipment

Caltrans District 12 TMC	Item	Price
Backroom Equipment	Video Decoder, Enerdyne DEC 2000R2 (qty 2)	$14,400
	Wide Area Communication Controller	$6,750
	Digital Service Multiplexer, Digital Link DL100 Encore	$3,737
	Airlink T1 Cable	$296
	T1 Access Unit, Cylink ALT1-OUAA-AU	$1,495
	GPS Receiver & Antenna, Trimble Placer 400	$645
	SVGA Monitor, NEC 14" Multisync C400	$365
	NTSC Video Monitor, JVC 14" TM-131SU	$330
	Keyboard, PC, Mitsumi KPQ-E99ZC-13	$35
	Cabinet, Free Standing	$2,111
	Camera Control Keyboard, American Dynamics Model 1676B	$499
Roof Equipment	Parabolic Solid Antenna, 2-ft diameter, Cylink 0807-0032	$890
	Roof Mount (Non Penetrating), Microreflect 99540	$499
	Yagi Antenna, Cushcraft/Signals PC904N	$40
	T1 SSR Radio, Cylink ALT1-4XAA	$7,995
Test Equipment	Bit Error Rate Tester	$495
	AutoScope Supervisor Computer, Bilink AS-SC486 with modem, digitizer, and software	$8,501
Service Equipment	Winch and Hydraulic Crane	$1,469
	Total	**$50,552**

Table 2-4. Anaheim TMC equipment

Anaheim TMC	Item	Price
	Spread Spectrum Radio (SSR) Components:	
	256 Kbps SSR, Cylink NSPALS256 EIA-530	$4,495
	64 Kbps SSR, Cylink ALSM64-05 AE EIA-530	$2,995
	Burst Synch Cable 13981-010	$50
	2-way RF Power Splitter /Combiner, Cylink ZAPD-4-N	$120
	Tripod, Non-Penetrating, 8-ft Antenna Mount, Microflect 91199	$345
	Parabolic Grid Antenna, 3-ft diameter, Comsat RSI P24A36GN1	$795
	Yagi Antenna, Cushcraft/Signals PC904N	$40
	Wide Area Communications Controller	$6,750
	Camera Control Keyboard, American Dynamics Model 1676B	$499
	Video Decoder, Enerdyne DEC2000R2	$7,200
	Video Monitor, JVC 14", TM-131SU	$330
	Keyboard, PC, Mitsumi KPQ-E99ZC-13	$35
	Total	**$23,654**

Table 2-5. UCI-ITS Laboratory equipment

UCI-ITS Laboratory	Item	Price
Equipment in bldg:	Video Decoder, Enerdyne DEC2000R2	$7,200
	Wide Area Communications Controller	$6,750
	SVGA Monitor, NEC 14" Multisync C400	$365
	Video Monitor, JVC 14" TM-131SU	$330
	Keyboard, PC, Mitsumi KPQ-E99ZC-13	$35
Equipment on roof:	Rectangular Non-Penetrating Antenna Mount, Microflect 99540	$499
	Equipment Cabinet	$500
	Spread Spectrum Radio (SSR) Components:	
	256 Kbps SSR, Cylink NSPALS256 EIA-530	$4,495
	64 Kbps SSR, Cylink ALSM64-05 AE EIA-530	$2,995
	2-way RF Power Splitter/Combiner, Cylink ZAPD-4-N	$120
	Yagi Antenna, Cushcraft/Signals PC904N	$40
	Parabolic Grid Antenna, 3-ft diameter, Comsat RSI P24A36GN1	$795
	S-Band Isolator, Cylink	$275
	Total	**$24,399**

Table 2-6. Relay site equipment

Relay Site	Item	Price
	Spread Spectrum Radio (SSR) Components:	
	256 Kbps SSR, Cylink NSPALS256 EIA-530 (qty 3)	$13,485
	64 Kbps SSR, Cylink ALSM64-05AE EIA-530 (qty 2)	$5,990
	Digital Service Multiplexer, Digital Link DL100 ENC-P-06	$3,737
	2-way RF Power Splitter/Combiner, Cylink ZAPD-4-N (qty 2)	$240
	3-way RF Power Splitter/Combiner, Cylink ZA30D-4-N	$180
	T1 SSR, Cylink ALT1-4XAA	$7,995
	T1 Mounting Kit	$150
	T1 Access Unit, Cylink ALT1-OUAA-AU	$1,495
	Antenna Cables and Mounting Kits	$1,900
	Omni Antenna, Vertically Polarized, SCALA MMV12/A MMDS/ITF	$16,848
	Antenna, 3-ft Parabolic Grid, Comsat RSI P 24 A36GN1 (qty 2)	$1,590
	Antenna, 2-ft Parabolic Solid, Cylink 0807-0032	$890
	Rectangular Non-Penetrating Antenna Mount, Microreflect 99540	$425
	Intelligent Power Controller, Pulizzi IPC 3102-2157	$1,074
	Junction Boxes	$300
	Equipment Cabinet	$500
	Roof Deck Walk Pads	$310
	Total	**$57,109**

Table 2-7. Equipment cost summary

Item	Unit Cost	Quantity	Total
Surveillance Trailers			
Trailer, Generator, Mast, etc.	$48,403	6	$290,418
Equipment	$76,560	6	$459,360
Subtotal	$124,963	6	*$749,778*
Ramp Meter Trailers			
Trailer, Generator, Signals, etc.	$40,334	3	$121,002
Equipment	$16,846	3	$50,538
Subtotal	$57,180	3	*$171,540*
Caltrans District 12 TMC	$50,552	1	*$50,552*
Anaheim TMC	$23,654	1	*$23,654*
UCI-ITS Laboratory	$24,399	1	*$24,399*
Relay Site	$57,109	1	*$57,109*
Grand Total			**$1,077,032**

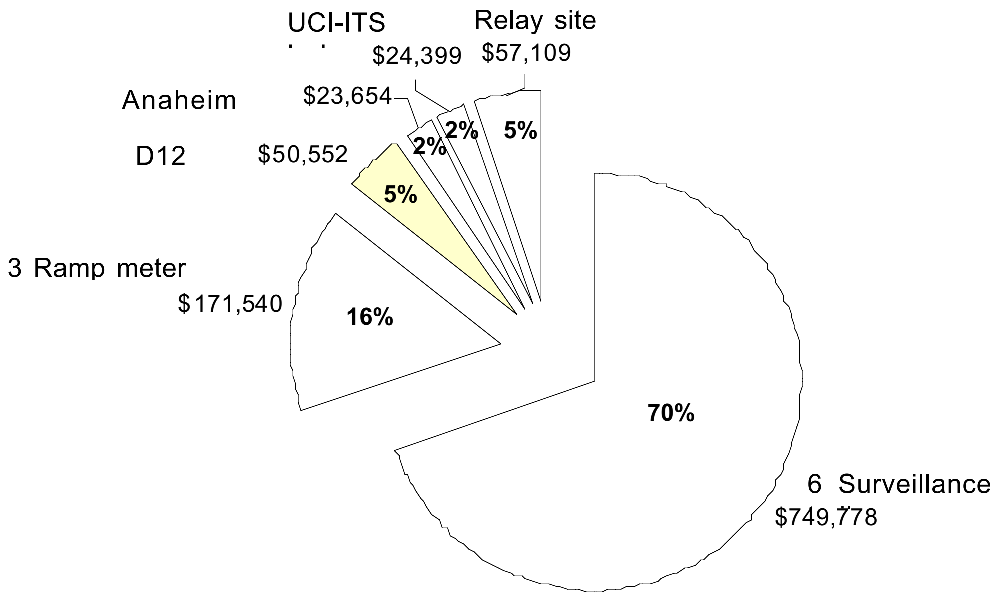


Figure 2-2. Relative contributions of the six surveillance trailers, three ramp meter trailers, District 12 and Anaheim TMCs, UCI-ITS Laboratory, and the relay site to the total equipment expenditure

3. Anaheim Special Event Test Evaluation

This section describes how the evaluation plan developed for the Anaheim Special Event Test was applied and discusses the test results. This test utilized three self-powered surveillance trailers to obtain and transmit video images via wireless SSR communications to the Anaheim TMC and the Caltrans District 12 TMC. Anaheim had the primary interest in the video and used it to modify traffic signal phases. The surveillance trailers were placed at intersections near the Arrowhead Pond in Anaheim where permanent video surveillance equipment did not exist.

3.1 Objectives

The five objectives of the Anaheim Special Event Test were designed to evaluate the use of the mobile surveillance trailers for special event traffic management.

- Objective1 examined the deployment of surveillance trailers to support a special event in a city within range of the relay site. To meet this objective, Caltrans and Hughes transported and set up the trailers and prepared written statements about the experience. The evaluators coordinated data collection, observed trailer deployment, received and analyzed data, and interviewed personnel.

- Objective 2 evaluated how well the surveillance trailers operated and supported the special event traffic management. To meet this objective, Anaheim TMC personnel observed the camera images and recorded test data. The evaluators coordinated data collection, observed camera use, received and analyzed data, and interviewed personnel.

- Objective 3 assessed the relative impact of the added video surveillance on special event traffic management. Anaheim TMC personnel observed traffic flow on the streets and exiting parking lots surrounding the Arrowhead Pond and recorded test data. The evaluators coordinated data collection, observed traffic flow, received and analyzed data, and interviewed personnel.

- Objective 4 assessed institutional issues, benefits, and costs related to sharing resources between agencies in support of special event traffic management. Caltrans and Anaheim personnel negotiated the use of the trailers by Anaheim and prepared written statements. The evaluators observed negotiations, received and analyzed written statements, and interviewed personnel.

- Objective 5 explored institutional issues, benefits, and costs related to sharing information between city and state agencies. Caltrans and Anaheim personnel negotiated the sharing of the video imagery and prepared written statements. The evaluators observed video sharing, received and analyzed written statements, and interviewed personnel.

3.2 Test Description

The Anaheim Special Event Test was conducted in conjunction with five special events, namely hockey games played April 1st, April 4th, April 9th, May 6th, and May 8th, 1997. At a PMT meeting following the May 8th game, it was determined that extending the test to additional events would not add useful information and, after approval by the partner agencies, the test was concluded.

Prior to the April 1st event, Caltrans District 12 delivered three surveillance trailers to the Arrowhead Pond area in the City of Anaheim. During the test, the surveillance trailers were under the control of the Anaheim TMC, which had the ability to power up and power down the trailers, select and position cameras, and select the image to be displayed on a monitor in the TMC. The video imagery could also be viewed at the Caltrans District 12 TMC. In this test, pan and tilt control were permitted for the two black-and-white VIP cameras since the VIP itself was not used. Hence, these black-and-white cameras were simply used as additional surveillance cameras. Pan, tilt, and zoom control was available for the color surveillance camera. Video imagery from the black-and-white security camera was also transmitted to both TMCs. Each trailer was equipped with a security alarm system connected to the District 12 TMC.

The images from the cameras were used by the TMC operators as if they were produced by a permanent camera. The operations personnel performed all other special event tasks in accordance with the Anaheim TMC Special Event Management Standard Operating Procedures. During the hockey games, when no manual traffic management was required, the TMC operations personnel worked with the Evaluation Team to record data in accordance with the Anaheim Special Event Test Evaluation Plan.

The Evaluation Team conducted an independent evaluation of the test results. The PMT supported the evaluation by providing the Evaluation Team with written reports concerning test activities, technology issues, institutional issues, and costs.

3.3 Test Evaluation

The measures of performance and data gathered to support the Anaheim Special Event Test objectives are discussed in this section.

3.3.1 Objective 1 –Portability

The first objective evaluated the portability of the surveillance trailers for use in a city special event setting within the range of the relay site. The measures of performance for this objective are listed below along with the data items that support each measure.

Measure 1.1: Pre-transport preparations

Data 1.1.1: Identity of pre-transport preparations

Data 1.1.2: Level of effort for pre-transport preparations

Measure 1.2: Time to hitch, transport, set in place, and make operational

Data 1.2.1: Number of minutes to hitch

Data 1.2.2: Number of minutes to transport

Data 1.2.3: Number of minutes to set in place

Data 1.2.4: Number of minutes to make operational

Measure 1.3: Transport and Setup Obstacles and Problems

Data 1.3.1: Identity of transport and set in place obstacles and problems

Data 1.3.2: Severity of obstacles and problems

3.3.1.1 Measure 1.1 - Pre-transport preparations

Data 1.1.1: Identity of pre-transport preparations

A number of planning meetings occurred prior to the actual deployment of the trailers. Based on these meetings, the evaluator assembled a preliminary list of pre-transport preparations and requested written statements from Caltrans District 12 confirming that this list was complete. The list below represents Data 1.1.1, the identity of the four pre-transport preparation activities:

- Preparation 1: Site Selection
- Preparation 2: Site Survey
- Preparation 3: Site Readiness
- Preparation 4: Trailer Readiness

Data 1.1.2: Level of Effort for pre-transport preparations

PMT members with relevant first-hand experience submitted written statements characterizing the efforts required for each pre-transport preparation. These statements may be found in Appendix A, which is located in Volume 3 of the Final Report. The evaluator conducted follow-up interviews, as necessary, to clarify and investigate essential issues. Anaheim project management reported spending 2 to 3 hours per day for 1 week in these activities. Anaheim field personnel reported spending 4 hours attending planning meetings and about 2 to 3 hours at each set of trailer deployments. The lead Caltrans engineer reported spending the better part of 1 year in these activities. Other Data 1.1.1 and 1.1.2 entries are summarized below.

Site Selection: Two special event venues were considered for this test, Anaheim Stadium (now named Edison International Field) and Arrowhead Pond. Arrowhead Pond was selected because the Mighty Ducks hockey game schedule provided more opportunities to utilize the trailers. A number of deployment sites around the Arrowhead Pond were considered. One important issue was identifying sites with enough space to accommodate the trailers. Since each of the surveillance trailers is 18’-8” (5.7 m) long and 7’-6” (2.3 m) wide, they are too large to be placed on city sidewalks. Consequently, parking lots became the deployment site of choice.
Another issue was finding sites where surveillance was needed and not already available from permanent surveillance equipment. Three locations were recommended.

These intersections are listed below in order of their value to the special event traffic management.

- Ball Road and Phoenix Club Drive
- Cerritos Avenue and Sunkist Street
- State College Boulevard and Cerritos Avenue

Site Survey: Each proposed site was investigated to determine if it was suitable for trailer deployment. The site survey process is outlined below.

- Step 1 - Confirm the identified property is available. Along city streets, parking lots are ideal except they are generally private property.

- Step 2 - Confirm adequate space for parking the surveillance trailers. Several parking spaces are required to accommodate the trailer.

- Step 3 - Confirm proper camera placement. Close placement to the road does not necessarily guarantee a usable view of traffic flow in the direction required for traffic management because of obstruction by trees, other foliage, power poles, transmission lines, buildings, and other structures.

- Step 4 - Confirm adequacy of received signal strength at the relay site. The signal must be strong enough at the relay site to retransmit video to the Anaheim TMC.

Hughes performed the signal strength testing (Step 4 above) at the three sites in 1996. Anaheim performed Steps 1 through Step 3 in March 1997. Anaheim personnel began the site selection process by viewing an aerial map and conducting site visits. They systematically eliminated intersections that did not have adequate space for parking the trailers. Having narrowed their options, property owners were identified and meetings held to ensure space availability on the days of the Arrowhead Pond events. When the event dates were finalized, a written agreement was prepared by Anaheim and signed by the property owners allowing the trailers to be situated on their property. Important factors in securing permission to use the desired property were:

- Conveying the importance of the tests to managing local traffic flow;

- Expressing the appreciation of the test partners for the cooperation of the property owners;

- Creating the least amount of intrusion into the normal operation of the property;

- Informing the owners of the precise length of time the surveillance trailers would be on their property and of the exact location of the trailers;

- Sending follow-up letters of appreciation to the property owners once the evaluation tests were completed.

Some rework of site survey tasks was required because of the sequence in which they were performed and the changes in personnel participating in different stages of the test. For example, Caltrans and Hughes used a bucket truck to check line-of-sight and measure radio signal strength at each of the three sites in 1996. Later, the proposed location at Ball Road and Phoenix Club Drive was found to have insufficient space for the trailer. Caltrans decided to then test the signal strength one block to the west near SR-57 at a location within the Caltrans right-of-way. This location had satisfactory signal strength and afforded the cameras a view Phoenix Club Drive. The exact placement of the trailer to optimize viewing of traffic and avoid tree interference with imagery and signal transmission was not found until the trailer was actually deployed. The final surveillance trailer location sites are listed below and shown in Figure 3-1.

- Ball Road at the Northbound onramp to SR-57
- Cerritos Avenue and Sunkist Street
- State College Boulevard and Cerritos Avenue.

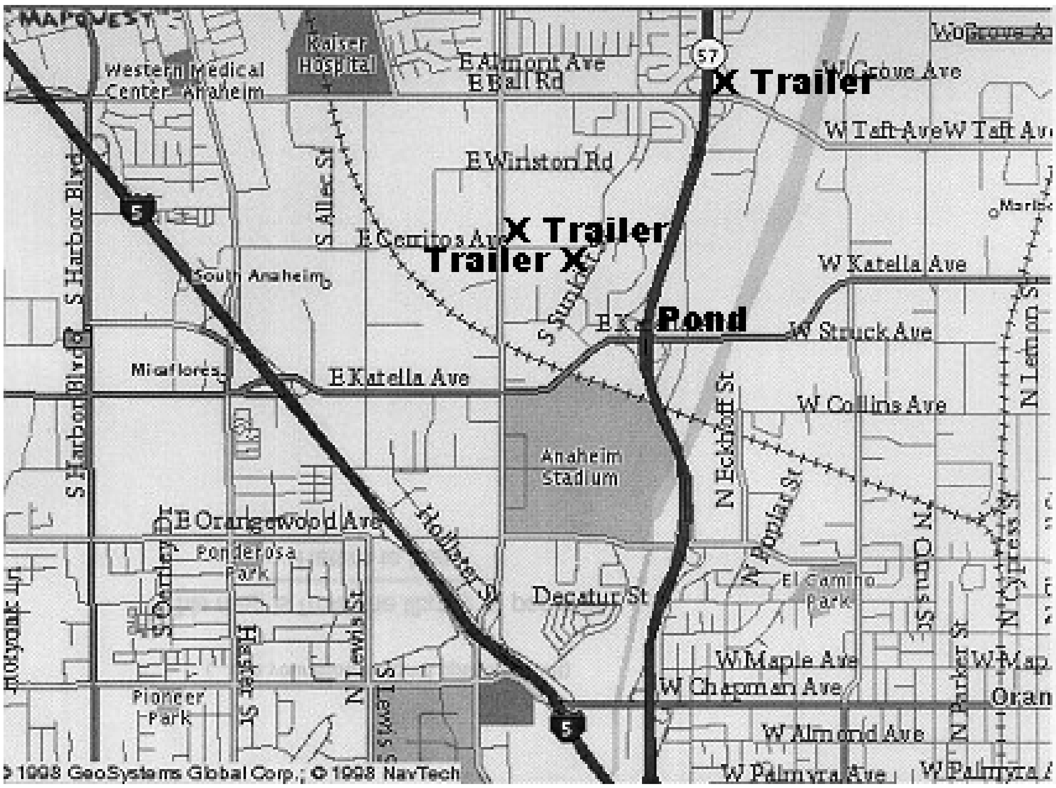


Figure 3-1. Surveillance trailer locations near the Arrowhead Pond

The trailers were placed in these locations for the April 1 event and then moved among the locations, prior to the other events, to gain more experience in transporting the trailers and to gather more data on trailer setup times.

Figures 3-2 through 3-4 show the trailers in position at the Anaheim Special Event Test sites.

Figure 3-2. Trailer being positioned at Cerritos Avenue and Sunkist Street

Figure 3-3. Trailer operational at Cerritos Avenue and Sunkist Street

Figure 3-4. Trailer operational at State College Boulevard and Cerritos Avenue

Site Readiness: Anaheim coned or taped off the lanes required for parking the surveillance trailer in the privately owned parking lots. Often, this was not required because a sufficient number of parking spaces was available in the parking areas. When needed, the parking lanes were reserved early in the morning or the night before the trailers were moved. Additional Caltrans vehicles were needed for a temporary ramp closure while moving the trailer into its test location in the Caltrans right-of-way at Ball Road and SR-57. Between the April 4 and April 9 events, the parking lots where two of the trailers had been located were scheduled for repaving. The property managers were contacted and they agreed to postpone the repaving by two weeks until after the test was complete.

Problems encountered during execution of the pre-transport preparations included:

- Identifying and contacting the property owners in the short time between the identification of the trailer location sites and the start of the first hockey game;

- Alleviating the property owners' concerns about hindering normal parking for the tenants and liability issues as these affected the willingness of the owners to give permission to use their property;

- Moving the trailers from site-to-site as this activity created more uncertainty for the property owners about trailer location, movement dates, and impact on their tenants. Availability of Caltrans personnel to move the trailers was also an issue associated with this problem;

- Since permission to park the trailers at the specified locations was based on earlier measurements of signal strength and camera view direction, trailers sometimes had to be relocated to improve the signal strength or camera view direction within the permitted trailer placement area.

Liability and theft issues concerning the surveillance trailers were not of primary concern to the property owners. However, they did want to know how accidents and thefts related to the FOT that occurred on their property would be handled. These issues were resolved through the inclusion of a clause in the permission agreement that contained language to the effect: "The City of Anaheim and Caltrans release the property managers and owners of any liability arising out of theft, vandalism, accidents, or damage to such trailers, except when intentionally caused." Prior to the issuance of this letter to the property owners by the City of Anaheim, Caltrans had provided a letter to Anaheim indicating that Anaheim would not incur major liability for damage to the trailers as long as reasonable care was taken in the use of the trailers. This release of liability by Caltrans assisted Anaheim in releasing the property owners, in turn, from liability.

Trailer Readiness: Caltrans engineering sent a notice to Caltrans maintenance ten days prior to the first trailer deployment informing them of the trailer deployment activities for the first three events. Caltrans maintenance supported the FOT by providing appropriate tow vehicles and assistance in closing the onramp at Ball Road and SR-57. At the conclusion of Event 3, maintenance personnel suggested that, upon completion of the FOT, a contractor be hired to transport the trailers so that normal Caltrans maintenance activities and responsibilities were not impacted by trailer moves.

Another issue involved with trailer readiness was scheduled trailer maintenance. Since trailer assembly was not complete when the Anaheim Special Event Test was conducted, a list of trailer maintenance tasks, schedule, and responsibility had not been finalized. The maintenance tasks that sometimes delayed trailer deployment included checking trailer tire pressure, checking generator oil level, checking battery water level, ensuring that safety chain clamps were available for each trailer, and checking liquid propane gas level for running the generator during the FOT events. The lists of scheduled maintenance and trailer turnon procedures eventually prepared by Hughes are found in Appendix B.

Other more serious delays were sometimes encountered. These arose from failures of the generator starter in some trailers and the failure of a battery due to lack of water. Another trailer experienced a failure in the data communications hardware.

After the deployment of Trailer #113 on March 26, prior to the first event, the Anaheim TMC could control the cameras, but not receive video. Hughes corrected this problem by fixing equipment at the Anaheim TMC.

The trailers were turned on and off manually as the automatic generator on/off system was not functioning properly. Often, it failed to turn the trailers off after the battery was recharged, causing fuel waste. The circuit has since been redesigned. Typically, the trailers were turned on manually by Caltrans or Hughes the day of the event, and turned off manually the day after the event. After Event 2, Hughes changed the oil and checked the battery water level in all three trailers used in the FOT.

On April 9, prior to the start of Event 3, Caltrans inspected the trailers to ensure that they were functioning. High winds had apparently shifted the antenna and camera positions. Hughes realigned the antennas so that the Anaheim TMC could again receive optimal video signals.

3.3.1.2 Measure 1.2 - Time to hitch, transport, set in place, and make operational

The evaluator observed each trailer transport and coordinated the collection of transport time data and observations. The data collected in support of the performance measures are:

Data 1.2.1: Number of minutes to hitch = "Hitched" minus "Began."

Data 1.2.2: Number of minutes to transport = "Arrived" minus "Hitched."

Data 1.2.3: Number of minutes to set in place = "Set" minus "Arrived."

Data 1.2.4: Number of minutes to make operational = "Departed" minus "Set."

The data for calculating the hitch, transport, set in place, and make operational times are listed in Table 3-1 for the five events. These data and relevant comments about the deployments were recorded on the data sheets shown in Appendix C.

The number of minutes to hitch, transport, set in place, and make operational are summarized in Table 3-2, as are the mean and standard deviation of the calculated performance measures. The standard deviation σ is given by

$$\sigma = \sqrt{\frac{\Sigma x_i^{\ 2}}{n} - \bar{x}^2} \tag{3-1}$$

where x_i is the value of an individual hitch, transport, setup, or make operational time; n is the number of entries (here equal to 12); and $\bar{x}$ is the mean value of the corresponding time.

Data 1.2.1: Number of minutes to hitch

The time to hitch had a moderate standard deviation value, due to the learning and problems experienced with the some of the trailer moves. The largest hitch times occurred when equipment, such as safety chain *D*-rings, was missing or when a trailer was not operational and attempts were made to repair it.

Data 1.2.2: Number of minutes to transport

Since the distances between the originating location and the destination location of the trailers varied, the standard deviation of the transport time was expected to be large. However, the value was relatively small in comparison with the other standard deviation values.

Table 3-1. Trailer hitched, arrived, set, and departed data

Event Number	Move Date	Trailer Number	Began	Hitched	Arrived	Set	Departed	Comments
1	3/26/9	111	8:00am	8:34am	8:59am	9:20am	9:48am*	Computer

	7						card failure
	3/26/97	113	10:13am	10:35am	11:05am	11:20am	12:30pm	Video not observable at Anaheim TMC
	3/27/97	115	8:03am	8:51am	9:12am	9:25am	9:52am	Trailer hitch raised; safety chain D-rings missing; had to travel to another trailer to borrow D-rings
2	4/2/97	115	8:10am	8:27am	8:31am	8:45am	9:07am	
	4/2/97	113	9:15am	9:34am	9:40am	9:50am	10:10am	
3	4/8/97	111	9:00am	9:32am	9:44am 11:01am	11:06am	11:20am	Temporarily stow trailer at SE corner lot
	4/8/97	115	9:49am	10:05am	10:28am	10:38am	10:45am	
4 and 5	5/6/97	115	7:35am	8:45am	9:02am	9:15am	9:16am*	Hughes presented
	5/6/97	113	9:32am	9:48am	10:10am	10:42am	10:55am	Weak signal at Anaheim TMC

* Checkout not completed for reasons stated in the table. Therefore, the time to make the trailer operational could not be calculated for this data set.

Data 1.2.3: Number of minutes to set in place

The set in place time showed some decrease as the number of trailer moves increased, demonstrating that learning took place. The relatively large setup time for Trailer 113 before Event 4 was caused by adjusting the trailer position several times in an attempt to increase the signal strength at the Anaheim TMC.

Data 1.2.4: Number of minutes to make operational

The make operational time also showed a downward trend as the number of trailer moves increased. The large make operational time for Trailer 113 at Event 1 was due to the time expended trying to correct the lack of video reception at the Anaheim TMC. If this large value for the make operational time is removed, the mean value of the make operational time is reduced to 17 minutes and the standard deviation to 7 minutes. The checkout of Trailer 111 on March 26 and Trailer 115 on May 6 were not completed during the initial portion of the move because of the problems noted in Table 3-1. Therefore, the make operational times for these trailer moves are not available.

Table 3-2. Hitch, transport, set in place, and make operational times

Event Number	Trailer Move Date	Trailer Number	Hitch Time (min)	Transport Time (min)	Set in Place Time (min)	Make Operational Time (min)
1	3/26/97	111	34	25	21	*
	3/26/97	113	22	30	15	70
	3/27/97	115	48	21	13	27
2	4/2/97	115	17	4	14	22
	4/2/97	113	19	6	10	20
3	4/8/97	111	32	12	5	14
	4/8/97	115	16	23	10	7
4 and 5	5/6/97	115	70	17	13	*
	5/6/97	113	16	22	32	13
Mean			30	18	15	25
Std. Deviation			18	8	7	19

* Checkout not completed because of problems listed in Table 3-1.

3.3.1.3 Measure 1.3 – Transport and Set in Place Obstacles and Problems

The two data items that supported this performance measure were the identity of transport and set in place obstacles and problems and their severity.

Data 1.3.1: Identity of transport and set in place obstacles and problems

The data sheets in Appendix C were reviewed for comments that indicated problems and obstacles encountered during transportation and deployment. Six problems were noted:

- Obstacle 1: Learning Curve
- Obstacle 2: Maneuverability
- Obstacle 3: Training
- Obstacle 4: Trailer Configuration
- Obstacle 5: Signal Interference
- Obstacle 6: Equipment Failure.

Data 1.3.2: Severity of obstacles and problems

Learning Curve: The times to hitch, transport and arrive, set in place, and make operational were reduced as personnel gained more experience with trailer transportation and operation. Exceptions to this general statement did occur when problems arose such as equipment failures, need to perform routine maintenance, or gathering of required equipment.

Maneuverability: One difficulty occurred while positioning the trailers in the parking lots with the large tow truck. It was at first thought that a smaller truck would allow greater ease of maneuvering and positioning of the trailers in confined areas. However, when the operator of the large tow truck was changed, the new operator had significantly less trouble backing and positioning the trailer. Therefore, the issue is one of tow truck operator training more than it is of the size of the tow vehicle.

Training: Training the Anaheim TMC staff in trailer placement and operation procedures was complicated by the fact that Hughes had not yet prepared a list of required actions and checks. However, the Anaheim staff learned what was required through a combination of verbal instructions and hands-on experience. An issue for future use of the surveillance trailers by Anaheim is finding a source of funds for the trailer transportation and setup.

Trailer Configuration: During transport of the ramp meter trailers, a solar powered signal head was placed too far forward on the trailer. This reduced the turn radius of the tow vehicle as the signal head interfered with the rear of the tow vehicle when it made a sharp turn. Although it might be unusual to make such a turn during normal transport, it is likely that such maneuvering would become necessary during normal positioning of the trailer. This problem was easily alleviated by repositioning the signal head on the trailer.

Signal Interference: The cameras on Trailer 115 produced a significant amount of color bar noise at the Anaheim TMC during Event 4. The trailer was moved several times in the parking area in an attempt to improve the signal strength. Some small improvements were noted during the test. However, the noise was never totally removed. This problem indicates the susceptibility of SSR technology to interference when the line-of-sight between transmitter and receiver is not clear.

Equipment Failure: On a number of occasions during the test, various trailer components failed to function. These problems were quickly remedied through the efforts of those present during the setup process. The types of problems involved a variety of trailer components ranging from one of the outriggers not functioning, difficulty in attaching safety chains to tow vehicles, to a failure of components on the automatic mast retraction system. These problems were considered minor. More thorough testing before deployment could potentially reduce the number of failures of this nature; however, it is unlikely that failures of this type can be completely avoided given the complexity of the trailers.

3.3.2 Objective 2 – Effectiveness of Trailers for Special Event Management

The second objective evaluated whether the surveillance trailers were effective for special event traffic management where traditional traffic management systems were not available. Anaheim TMC personnel observed the camera images and entered their findings on data sheets that were analyzed by the evaluators. The measures of performance for this objective are listed below along with the data items that support each measure.

Measure 2.1: Camera image and control availability

Data 2.1.1: Camera image percent up time

Data 2.1.2: Camera control percent up time

Measure 2.2: Camera image and control problems

Data 2.2.1: Identity of camera image and control problems

Data 2.2.2: Severity of camera image and control problems

3.3.2.1 Measure 2.1: Camera image and control availability

Test data were collected by Anaheim TMC special event operators. The operators were given Camera Operability Data Sheets on which to record the quality of the camera image and camera control. A "check" (√) mark indicated that image or control was available and an "x" indicated that image or control was unavailable. Whenever an "x" was entered, the operator indicated the nature of the problem on the data sheets found in Appendix D. Figure 3-5 shows the Anaheim TMC work area with the camera control keyboard on the desk and monitor on a counter in the background.

Figure 3-5. Anaheim TMC work area

Data 2.1.1 Camera image percent up time

Camera image percent up time was determined from the ratio of the number of times the image was clear divided by the number of times the image clarity was polled. The percent of time the camera image was clear (Data 2.1.1) was calculated with data from the five test events. The results are given in Tables 3-3 to 3-5 for Trailers 111, 113, and 115, respectively. Camera 1 denotes the color surveillance camera, Camera 2 the first VIP black-and-white camera, Camera 3 the second VIP black-and-white camera, and Camera 4 the black-and-white security camera.

Although the initial evaluation plan called for checks every 15 minutes, it was soon obvious that the checks did not have to be performed this often for several reasons. First, a round of checks took 15 minutes in itself. Therefore, the original schedule would have required continuous testing of the camera image and control for the duration of the special event. Second, experience showed that the camera controls were reliable and the imagery stable (except that from the color camera as darkness fell). Therefore, the interval between tests was lengthened to 45 minutes and then to 1 hour.

Table 3-3. Trailer 111 camera image availability

Camera Number	# Available/# Checks	Percent
1	10/14	71%
2	10/14	71%
3	11/14	79%
4	11/14	79%

Table 3-4. Trailer 113 camera image availability

Camera Number	# Available/# Checks	Percent
1	27/32	84%
2	27/32	84%
3	31/32	97%
4	31/32	97%

Table 3-5. Trailer 115 camera image availability

Camera Number	# Available/# Checks	Percent
1	21/31	68%
2	29/31	94%
3	29/31	94%
4	29/31	94%

Data 2.1.2: Camera control percent up time

Camera control percent uptime was defined as the ratio of the number of times control was available divided by the number of times the control functions were polled. The percent of time camera control was available (Data 2.1.2) was obtained from the data sheets filled out by the TMC operators. Two types of tables are used to summarize Data 2.1.2 as illustrated in Tables 3-6 to 3-8 corresponding to the three trailers. Table (a) for each trailer denotes the percent of time camera control was available for all cameras on a trailer. Table (b) provides the percent of time each camera was available on the trailer. In some instances, control could not be determined because the image was unavailable. If control was consistently available for all checks prior to then, it was assumed that control was available even when the image could not be clearly seen. If control was unavailable for checks prior to losing image quality, then it was assumed that control was unavailable during the period of degraded imagery. The camera designations are the same as for the preceding tables. When a function test is not applicable, the "n/a" symbol is inserted in the table.

Table 3-6. Trailer 111 camera control availability

(a) All camera data

Function	# Available/# Checks	Percent
Pan	36/42	86%
Tilt	36/42	86%
Zoom	12/14	86%

(b) Individual camera data

Camera	Pan		Tilt		Zoom	
1	12/14	86%	12/14	86%	12/14	86%
2	12/14	86%	12/14	86%	n/a	n/a
3	12/14	86%	12/14	86%	n/a	n/a
4	n/a	n/a	n/a	n/a	n/a	n/a

Table 3-7. Trailer 113 camera control availability

(a) All camera data

Function	# Available/# Checks	Percent
Pan	93/96	97%
Tilt	93/96	97%
Zoom	31/32	97%

(b) Individual camera data

Camera	Pan		Tilt		Zoom	
1	31/32	97%	31/32	97%	31/32	97%
2	31/32	97%	31/32	97%	n/a	n/a
3	31/32	97%	31/32	97%	n/a	n/a
4	n/a	n/a	n/a	n/a	n/a	n/a

Table 3-8. Trailer 115 camera control availability

(a) All camera data

Function	# Available/# Checks	Percent
Pan	100/100	100%
Tilt	100/100	100%
Zoom	31/31	100%

(b) Individual camera data

Camera	Pan		Tilt		Zoom	
1	31/31	100%	31/31	100%	31/31	100%
2	31/31	100%	31/31	100%	n/a	n/a
3	31/31	100%	31/31	100%	n/a	n/a
4	n/a	n/a	n/a	n/a	n/a	n/a

3.3.2.2 Measure 2.2: Camera image and control problems

Camera image and control problems were identified by Anaheim TMC Special Event Operators and were recorded on Part II of the Camera Operability Data Sheets as shown in Appendix D.

Data 2.2.1: Identity of camera image and control problems

Tables 3-9a through 3-9e show that at no time during the five events in the test was the ability to control or switch cameras lost. However, some learning was required to use the camera control keypad before the camera could be positioned by the operator. The problems with camera control were identified by reviewing the data sheets presented to the evaluator. Image quality is a function of the camera design specifications, ambient lighting, and camera placement relative to the subject of interest.

Table 3-9a. Camera control and imagery problems experienced on April 1, 1997

Trailer 111	Not operational due to computer card failure. This trailer location was deemed the most valuable for traffic management at this event.
Trailer 113	Trees and road geometrics limited the downstream view of traffic when the color cameras on 113 and 115 were zoomed. Black-and-white camera provided an excellent view of traffic arrival and dispersion at the intersection.
Trailer 115	Black-and-white camera allowed surveillance of traffic arrival in the advanced detection setback zone and of mid-intersection traffic.

Table 3-9b. Camera control and imagery problems experienced on April 4, 1997

Trailer 111	Trailer 111 operational. Provided an unobstructed view of downstream signal at ball road and phoenix club drive.

Trailer 113	Same comment as for event 1.
Trailer 115	Provided an improved view of the desired traffic flow.

Table 3-9c. Camera control and imagery problems experienced on April 9, 1997

Trailer 111	Camera perspective and view from all cameras at all trailers were the same as in the previous event. Heavy winds may have caused weak reception of video at the TMC. However, camera control functions worked satisfactorily at all the trailers.
Trailer 113	Non-responsive to remote control commands for the cameras. Repairs by Hughes completed after the start of the inbound traffic flow for the event.
Trailer 115	Weak signal reception at TMC (color bars observed on video monitor). Repairs by Hughes completed after the start of the inbound traffic flow for the event.

Table 3-9d. Camera control and imagery problems experienced on May 6, 1997

Trailer 111	Not Used
Trailer 113	The imagery from one of the black-and-white cameras was observed to change color on the monitor in the TMC, apparently from loss of video synch due to a weak signal.
Trailer 115	Imagery useful in setting timing plan for traffic exiting the Pond and turning left onto Sunkist toward Katella Avenue. Traffic was observed to be getting heavier, allowing the TMC operator to change the timing plan to allow for maximum left-turn signal time.

Table 3-9e. Camera control and imagery problems experienced on May 8, 1997

Trailer 111	Not Used.
Trailer 113	Color camera image lost clarity as it became dark outside.
Trailer 115	No comments reported.

Observations made by Caltrans personnel from the video tape of the traffic flow, as recorded by the Ball Road and SR-57 surveillance trailer, indicated that it was easy to differentiate between cars and trucks and to estimate the number of vehicles. There was a little glare from some headlights that were pointed in the direction of the cameras; however, this did not cause a problem in observing the flow of traffic.

The imagery from the color camera degraded as darkness fell and less background lighting was available. This effect was not observed with the permanently installed CCTV cameras currently in use by the City of Anaheim. Therefore, it appears that higher sensitivity color cameras can be procured if additional surveillance trailers are built. Another type of image degradation occurred when the signal transmitted to the Anaheim TMC was weak. Under these conditions, the black-and-white image was observed to change color on the monitors in the TMC. The antenna on the trailers was realigned in an attempt to correct this problem. More often than not, the weak signal reception persisted.

However, the imagery received at the TMC still provided satisfactory information for traffic management purposes.

3.3.3 Objective 3 - Benefits of Additional Surveillance

The third objective of the Anaheim Special Event Test was to compare the time it took the parking lots to empty with and without the use of cameras at locations where permanent video surveillance was not available. Anaheim personnel provided the relevant traffic egress data, which were analyzed by evaluators. The evaluators also accompanied Anaheim Traffic Officers in their vehicles during the first three events to observe traffic management strategies. Comments obtained from interviews and the evaluators' observations are noted in Data 3.1.2. The measure of performance for this objective is:

Measure 3.1: Decrease in event traffic egress duration with temporary video surveillance

Data 3.1.1: Average event traffic egress duration without mobile surveillance trailers

Data 3.1.2: Average event traffic egress duration with mobile surveillance trailers

Data 3.1.1: Average egress duration without mobile surveillance trailers

Five major freeways connecting with different regions of Orange and Los Angeles Counties service Arrowhead Pond. Several major surface streets, including Katella Avenue and Ball Road, lead to the arena's seven parking lots. More than 4,500 parking spaces are located within walking distance of the Pond's main entrance. Limousine, bus, and handicap parking are located adjacent to the arena. Therefore, there is heavy traffic flow out of the Pond after a sell-out event.

Table 3-10 shows historical parking lot egress data gathered between January 6, 1997 and March 14, 1997 over the course of 10 events at the Arrowhead Pond. The average attendance for these events was 17,240. The average egress duration was 52.7 minutes, with a standard deviation of 12.2 minutes.

Table 3-10. Historical times to empty parking lot (without mobile surveillance trailers)

Date	Attendance	Event End Time	Outbound End Time	Egress Duration (min)
1/6/97	17,012	22:00	22:45	45
1/8/97	17,182	21:54	23:00	66
1/10/97	17,398	22:20	22:55	35
1/22/97	17,231	22:02	22:50	48
1/31/97	17,372	21:52	23:00	68
2/26/97	17,246	22:15	23:10	55
3/5/97	Not available	21:40	22:45	65
3/7/97	Not available	22:25	23:00	35
3/12/97	Not available	22:00	23:00	60
3/14/97	Not available	22:00	22:50	50

Data 3.1.2: Average event traffic egress duration with mobile surveillance trailers

Table 3-11 shows the parking lot egress duration measured for the five events. The average parking lot egress duration was 36.2 minutes, with a standard deviation of 1.9 minutes. This average is approximately 31 percent less than the average historical egress duration. The 36.2-minute time represents an average egress period that is 1.3 standard deviations less than the historical average egress duration. The analysis of this limited amount of data indicates that the egress times for Events 1 to 5 also had a smaller standard deviation that did parking lot egress when the mobile surveillance cameras were not present. However, the data sample is too small to substantiate these statistics with high confidence. Other factors, described below, may have contributed to the larger egress durations and standard deviation recorded in the historical database.

Table 3-11. Times to empty parking lots at Arrowhead Pond during Events 1 to 5 (with mobile surveillance trailers)

Event Number*	Date	Event End Time	Outbound End Time	Egress Duration (min)
1 (Hockey only)	Tuesday April 1, 1997	22:42	23:17	35
2 (Hockey & baseball)	Friday April 4, 1997	22:15	22:55	40
3 (Hockey & baseball)	Wednesday April 9, 1997	22:20	22:56	36
4 (Hockey only)	Tuesday May 6, 1997	22:40	23:15	35
5 (Hockey only)	Thursday May 8, 1997	0:25	1:00	35

* The hockey games were sold out for the above 5 events. The baseball game was held at neighboring Anaheim Stadium.

Anaheim attributes the variability in the historical egress durations to differences in the expertise of individual event operators, daily fluctuations in field conditions, and the accuracy of recorded times. It is not unlikely that the five test events had less variability simply because great care was taken during the FOT events to accurately record event end time and outbound end time.

The evaluation team observed that much of the traffic congestion on Katella Avenue in front of the arena was due to heavy pedestrian traffic. Police gave priority to pedestrians in order to prevent large, uncontrollable pedestrian groups from forming.

Police officers controlling the egress did not believe their unit was consulted about optimum trailer placement. If the trailers are to be successfully used in the future to supplement existing traffic controls and strategies, all interested parties should have input.

3.3.4 Objective 4 - Institutional Issues: Resource Sharing

The fourth objective of the Anaheim Special Event Test evaluated institutional issues, benefits, and costs related to sharing resources among agencies participating in managing a city special event. The objective was met by observing pre-test activities and interviewing personnel involved with the various aspects of the test. The measures of performance and supporting data for this objective are:

Measure 4.1: Advantages of resource sharing

Data 4.1.1: Identity of advantages of resource sharing

Measure 4.2: Disadvantages of resource sharing

Data 4.2.1: Identity of disadvantages of resource sharing

Measure 4.3: Costs of resource sharing

Data 4.3.1: Identity of cost items related to resource sharing

Many members of the PMT and their supporting staff had first-hand experience with resource sharing between Anaheim and Caltrans. Consequently, they were able to supply the advantages of resource sharing. The evaluator prepared an initial list of advantages and disadvantages and requested written statements from team members to confirm that the list was complete and to identify cost items. The evaluator conducted follow-up interviews with Caltrans and Anaheim engineers regarding the advantages and disadvantages of resource sharing.

Data 4.1.1: Identity of advantages of resource sharing

The advantages of resource sharing as determined from the PMT members were:

- Advantage R1: Provides surveillance at Anaheim street locations that do not have permanent cameras
- Advantage R2: Facilitates inter-agency cooperation between the Anaheim TMC and Caltrans District 12
- Advantage R3: Provides resources for future traffic management at intersections undergoing construction
- Advantage R4: Determines effectiveness of placing a camera at a location prior to incurring costs associated with permanent installation
- Advantage R5: Stimulates ideas for future projects
- Advantage R6: Provides insight into viability of future projects
- Advantage R7: Directly provides Caltrans with information about upcoming freeway traffic following special events.

Data 4.2.1: Identity of disadvantages of resource sharing

The disadvantages of resource sharing as determined from the PMT members were:

- Disadvantage R1: Requires complex inter-agency coordination
- Disadvantage R2: Requires Caltrans to limit city liability

- Disadvantage R3: Requires city to acquire new expertise
- Disadvantage R4: Requires special security arrangements
- Disadvantage R5: Requires extra training for city personnel
- Disadvantage R6: City police cannot provide special monitoring for trailers
- Disadvantage R7: Requires special arrangements for locating trailers on private property
- Disadvantage R8: Benefits not commensurate with amount of human, time, and fiscal resources required to utilize the trailers.

Data 4.3.1: Identity of cost items related to resource sharing

The cost items determined from statements prepared by PMT members were:

- Cost Item R1: Caltrans delivery of trailers
- Cost Item R2: City participation in trailer setup
- Cost Item R3: Installation of equipment at the Anaheim TMC
- Cost Item R4: Training of Anaheim personnel
- Cost Item R5: Upkeep of Anaheim radio receivers and other equipment
- Cost Item R6: Exposure to liability
- Cost Item R7: Increased insurance costs
- Cost Item R8: Opportunity costs
- Cost Item R9: Maintenance and service per 100 hours use.

3.3.5 Objective 5 - Institutional Issues: Information Sharing

The fifth objective of the Anaheim Special Event Test assessed institutional issues, benefits, and costs related to sharing the video information between city and state agencies. This was accomplished by observing pre-test activities and interviewing traffic operations personnel about their use of information for managing special events. The measures of performance and supporting data are:

Measure 5.1: Advantages of event traffic video sharing

Data 5.1.1: Identity of advantages of traffic video sharing

Measure 5.2: Disadvantages of event traffic video sharing

Data 5.2.1: Identity of disadvantages of traffic video sharing

Measure 5.3: Costs of information sharing

Data 5.3.1: Identity of cost items related to information sharing.

Many members of the PMT and their supporting staff had first-hand experience with the decision to provide video sharing between Anaheim and Caltrans. Consequently, they were able to name the advantages of information sharing. The evaluator prepared an initial list of advantages and disadvantages of video sharing and requested written statements from team members to confirm the completeness of the list and to identify cost items. The evaluator conducted follow-up interviews with TMC operators concerning the advantages and disadvantages, and an interview with the lead city field technician regarding potential cost items.

Data 5.1.1: Identity of advantages of event traffic video sharing

The advantages of event traffic video sharing determined from PMT members were:

- Advantage R1: Allows Caltrans District 12 to better manage freeway operations in the vicinity of the Arrowhead Pond
- Advantage R2: Facilitates inter-agency cooperation between the Anaheim and Caltrans District 12
- Advantage R3: Provides each agency with a better understanding of the other's operations
- Advantage R4: Directly provides Caltrans with information about upcoming freeway traffic following special events.

Data 5.2.1: Identity of disadvantages of event traffic video sharing

The disadvantages of event traffic video sharing determined from PMT members were:

- Disadvantage R1: Requires operators at different facilities to share common video controls
- Disadvantage R2: Requires prioritizing camera control and, hence, limiting primary control to one agency
- Disadvantage R3: Increases potential for technical problems if planning meetings and tests are not conducted.

Data 5.3.1: Identity of cost items related to information sharing

The cost items related to information sharing determined from PMT members were:

- Cost Item R1: State and city power consumption
- Cost Item R2: Initial installation of equipment at the Anaheim TMC.

3.3.6 Issues Indirectly Related to the Anaheim Special Event Test

During the field operational test, several problems or obstacles were noted through direct observation, interviews, or prepared statements. These items were related to the test, but not directly linked to any specific test objective. They include ATMS software icon and database setup, training for accessing the database, trailer malfunctions associated with trailer turnon and turnoff, delayed camera control response, image blooming, and obstacles to trailer refueling.

3.3.6.1 ATMS Icon and Database Setup and Training

Moving the surveillance trailers from I-5 to the locations needed for the Anaheim Special Event Test required modification of the trailer and camera selection icons and corresponding ATMS database. This marked the first time that Caltrans staff had to create the icons and database. Previously, NET had performed these tasks. Therefore, there was a learning curve for Caltrans, causing the icons not to be ready for the first Anaheim Special Event Test event. In addition, rebooting of the ATMS was required once the new trailer and icon locations were in place. The need to restart the system was not known to Caltrans until they tried to use the new icon set. The problems in setting up the new icons did not adversely impact control and operation of the surveillance trailers by the Anaheim TMC. However, they did hamper the process of trailer and camera control from the Caltrans District 12 TMC.

3.3.6.2 Malfunction Associated with Trailer Turn-on and Turn-off

At Event 1, all trailer generators were turned on and off remotely from the Anaheim TMC. However, the poor reliability of the remote on/off system caused the trailer's generator to run for long periods of time without turning off, depleting the liquid propane gas fuel quicker than expected. Therefore, at later events the trailers were turned on and off manually before and after the events. A microprocessor-controlled on/off battery charging system has since been designed and installed in the six surveillance trailers.

3.3.6.3 Delayed Camera Control Response

At Event 2, a delay occurred between the issuance of a pan, tilt, or zoom command (by the TMC camera control unit at Anaheim) for a trailer-mounted color camera and its execution by the pan, tilt, and zoom assembly on the trailer. This delay was observed on the monitor at the Anaheim TMC by noting the delay time for the image to change as compared to the time of command initiation at the TMC. Telephone conversations with the District 12 TMC confirmed the change in pan, tilt, or zoom, even though the change was not observed as yet at the Anaheim TMC.

Another type of delay was associated with the compressed video. It caused the operator to pass through the desired camera pan or tilt setting. The operator noted, however, that with some training this deficiency was overcome.

3.3.6.4 Image Blooming

Operators experienced blooming when panning near or through streetlights during nighttime viewing. This was not judged a major problem. The black-and-white cameras did provide sharp images, however.

3.3.6.5 Obstacles to Trailer Refueling

Before Event 3, difficulties in getting the trailers refueled prevented the systems continuity check from being performed at the new trailer locations.

4. I-5 Test Evaluation

4.1 Objectives and Performance Measures

The evaluation of the surveillance and ramp meter trailers in support of freeway ramp metering had quantitative and qualitative objectives as listed in Table 4-1. Objectives 1 and 2 had quantitative and qualitative components, while Objectives 3 and 4 were qualitative.

Table 4-1. Linkage of I-5 Test objectives to quantitative and qualitative aspects of the evaluation

Objective	Test Type	Supporting Data	Where Discussed
1. Examine portability of the surveillance and ramp meter trailers	Quantitative	Measurements of trailer hitch, transport, set in place, and make operational times	Section 4.6.1
	Qualitative	Identify issues associated with selecting the evaluation sites and transporting the trailers	Section 4.6.1
2. Demonstrate satisfactory operation of the surveillance and ramp meter trailers at freeway locations where permanent traffic management systems are disabled	Quantitative	Comparisons of measured ILD and VIP traffic flow parameters output by 170 controllers	Section 4.6.2, 4.8, 4.9, 4.10
	Qualitative	Monitor reception of video and data; exercise camera pan, tilt, and zoom controls and trailer turnon, turnoff, and alarm functions	Section 4.6.2
3. Examine institutional issues, benefits, and costs associated with deploying surveillance and ramp meter trailers in a freeway setting	Qualitative	Interviews to seek critiques, suggestions, costs, and advantages and disadvantages of freeway trailer deployment	Section 4.6.3, 4.11
4. Examine institutional issues associated with sharing freeway video and data information among Caltrans, Anaheim, and the ITS Laboratory at UCI	Qualitative	Interviews to seek critiques, suggestions, and advantages and disadvantages of information sharing	Section 4.6.4

Objective 1 examined the portability of the surveillance and ramp meter trailers by (1) measuring the time to hitch, transport, set in place, and prepare the trailers for operation and (2) identifying the issues associated with deploying the trailers. The Anaheim Special Event Test had an identical objective.

Objective 2 also had quantitative and qualitative components. The quantitative portion determined how well the surveillance and ramp meter trailers met their intended goal of performing the ramp-metering function. It compared inductive loop detector (ILD) and video image processor (VIP) mainline and onramp traffic flow data. The traffic parameters measured by these sensors were processed by two 170 computers, one assigned to the ILD data and one to the VIP data. Laptop computers, connected to each of the 170 controllers through a serial port, recorded the processed data in 30-second intervals and, thus, simulated the data polling normally performed by computers at the TMC. Caltrans developed the data recording and analysis programs that facilitated the comparison of mainline lane occupancies and volumes, ramp signal demand, and ramp-metering rates computed from the ILD and VIP measurements.

The qualitative evaluation associated with Objective 2 occurred in the Caltrans District 12 and Anaheim TMCs and the ITS Laboratory at UCI. Personnel at these locations monitored the reception of video and data and exercised the surveillance camera pan, tilt, and zoom controls and the trailer turnon, turnoff, and alarm functions to the extent that their facilities permitted. The Caltrans District 12 TMC received video imagery and data from the three pairs of trailers performing ramp metering and video from the other three surveillance trailers. District 12 had the ability to remotely control VIP calibration and camera selection and positioning. The Anaheim TMC received video, but not data, from all the trailers and had control of camera selection and positioning. The UCI-ITS Laboratory received video imagery from the trailers, but could not select or control the cameras.

Objective 3 was qualitative. It identified the advantages, disadvantages, and costs associated with selecting the evaluation sites, transporting the trailers to them, and using the data for traffic management. Comments were solicited from Caltrans personnel involved with site selection, scheduling, performing the evaluation; TMC operations; and maintenance personnel who transported the trailers.

Objective 4, also qualitative, examined the institutional issues associated with sharing freeway video and data information among Caltrans, Anaheim, and the ITS Laboratory at UCI. Comments were solicited from Caltrans, Anaheim, and UCI personnel involved with scheduling and performing the evaluation and Caltrans and Anaheim TMC operations personnel.

After the I-5 Test began, Caltrans and the evaluator decided it would be beneficial to place one surveillance trailer in an actual construction zone to uncover the problems associated with such a deployment. Two sites were used in this portion of the study. The first location at Katella Avenue and I-5 was short lived as the contractor discovered that the trailer would interfere with his contractual road improvement responsibilities. After several weeks, an alternative site was found at the Katella Way onramp to the southbound I-5 near Manchester Avenue.

4.2 I-5 Test Locations

The maps in Figures 4-1 through 4-3 show the locations of the six surveillance trailers at Main Place, Grand Avenue, First Street, Tustin Ranch Road, Jamboree Road, and Culver Drive evaluation sites in north to south order along I-5. All, but the First Street trailer, were on the northbound side of the freeway. The relay site that retransmitted video and data from the surveillance trailers to the TMCs at Caltrans District 12 and Anaheim and to the ITS Laboratory at UCI is also indicated in Figure 4-2. During the evaluation, the trailers were powered from liquid propane fueled generators and storage batteries. The only exception was the surveillance trailer at Culver Drive that was connected to public utility landline power. With generator power, the unique aspects of trailer portability and reliability could be evaluated. On the other hand, the public utility power supplied to at least one trailer also allowed the alternate power system to be evaluated. Portable ramp meter trailers, including signal heads and meter-on signs, were placed at Grand Avenue, Tustin Ranch Road, and Jamboree Road. These locations were selected because they had ample room for the portable signal heads, ramp meter trailers, and meter-on signs. Photographs of the trailers and other equipment at the evaluation sites are shown in Figures 4-4 to 4-10.

The meter-on sign at Jamboree Road in Figure 4-9 is covered because it was not operational at the time this photograph was taken. The portable signal heads were placed in front of the permanent ones, which were covered to prevent confusion. Figures 4-11 to 4-16 contain layouts of the surveillance and ramp meter trailer placement at the six locations. Grand Avenue was the only site to use two ramp meter signal heads.

Table 4-2 lists the trailer identification numbers, number of ramp lanes metered, number of ramp meter signals deployed, and number of meter-on signs used at each site. All the surveillance trailers were used in support of the portability, image quality, and camera control portions of the quantitative evaluation. The trailers at the three ramp-metering locations were used to support the comparison of the ILD and VIP mainline and onramp data.

Table 4-2. Trailer and site deployment information

Site	Surveillance Trailer Number	Ramp Meter Trailer Number	Number of Ramp Lanes	Ramp Meter Signal Heads Deployed	Meter-on Sign Deployed
Main Place	115	n/a	n/a	n/a	n/a
Grand Avenue	109	17368	2	2	1
First Street	113	n/a	n/a	n/a	n/a
Tustin Ranch Road	114	17369	2	1	0
Jamboree Road	110	19280	2	1	1
Culver Drive	111	n/a	n/a	n/a	n/a

n/a = not applicable

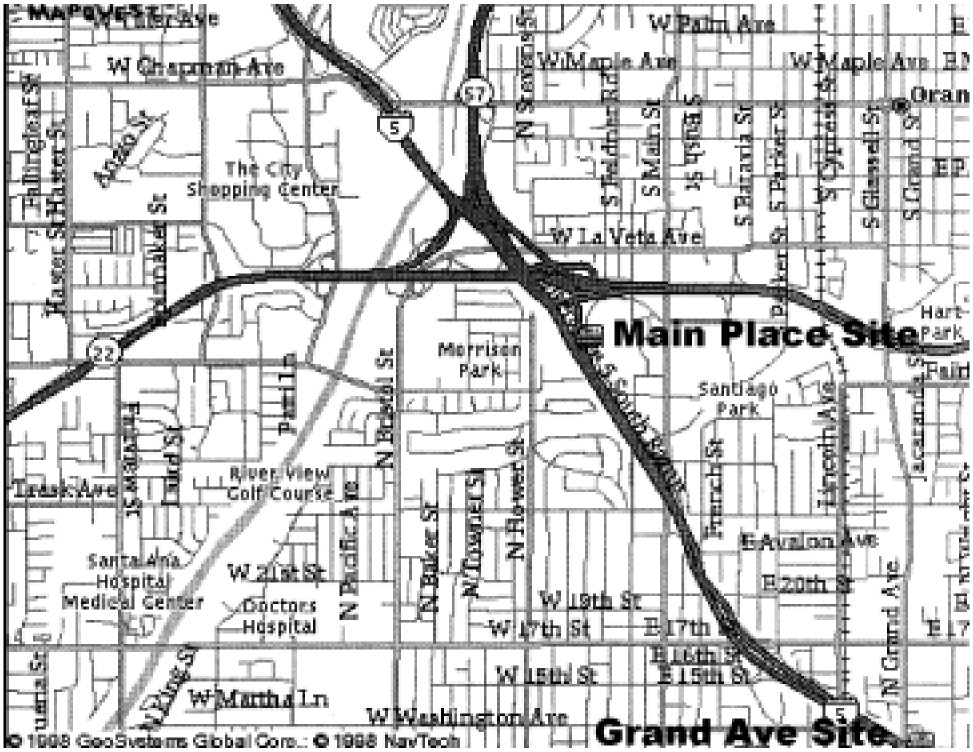


Figure 4-1. Main Place and Grand Avenue evaluation site locations along I-5

Figure 4-2. Grand Avenue and First Street evaluation site locations along I-5 and relay site on North Main Street between 10th and 11th Streets

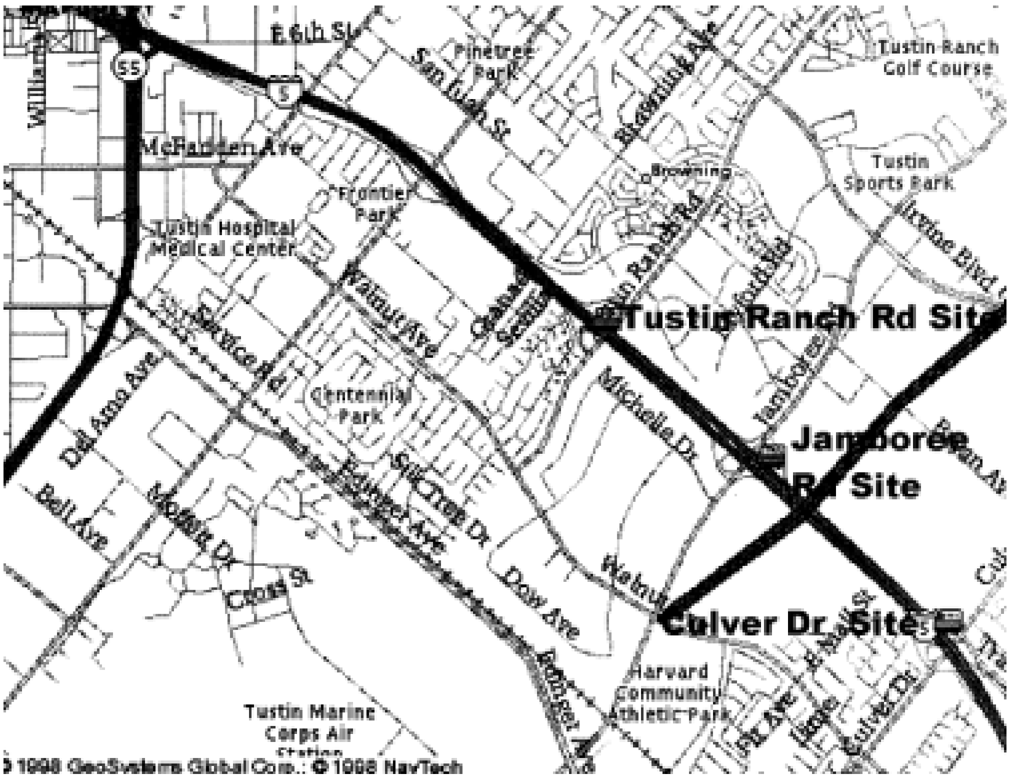


Figure 4-3. Tustin Ranch Road, Jamboree Road, and Culver Drive evaluation site locations along I-5

Figure 4-4. Surveillance trailer at Main Place looking south along I-5

(a) Surveillance trailer

(b) Ramp meter trailer

(c) Ramp signals

Figure 4-5. Surveillance and ramp meter trailers and signals at Grand Avenue

Figure 4-6. Surveillance trailer at First Street

Figure 4-7. Surveillance and ramp meter trailers at Tustin Ranch Road

(a) Onramp with surveillance trailer on left, ramp meter trailer and signal on right

(b) Surveillance trailer alongside of I-5 freeway

(c) Ramp meter trailer and signal

Figure 4-8. Surveillance and ramp meter trailers at Jamboree Road

Figure 4-9. Meter-on sign with solar panel at Jamboree Road ramp entrance

(a) Trailer and tow truck

(b) Trailer in position with mast extended

Figure 4-10. Surveillance trailer at Culver Drive

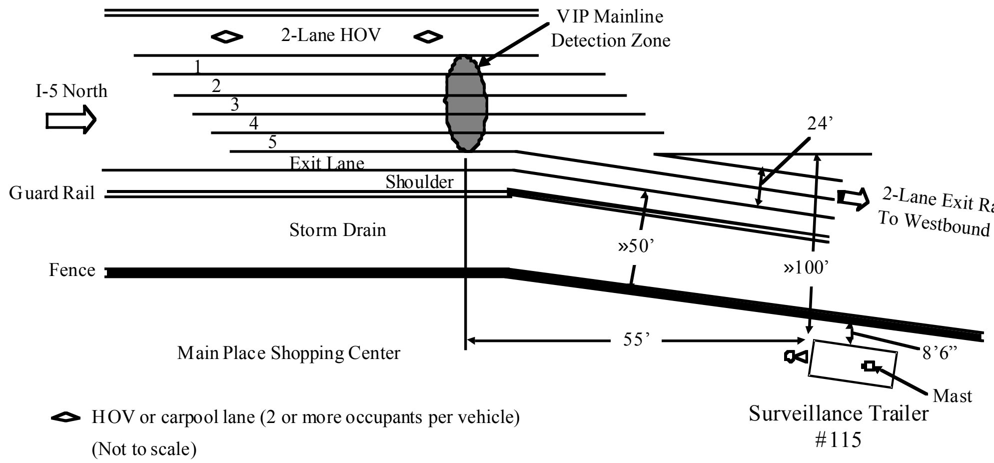


Figure 4-11. Trailer configuration at Main Place evaluation site

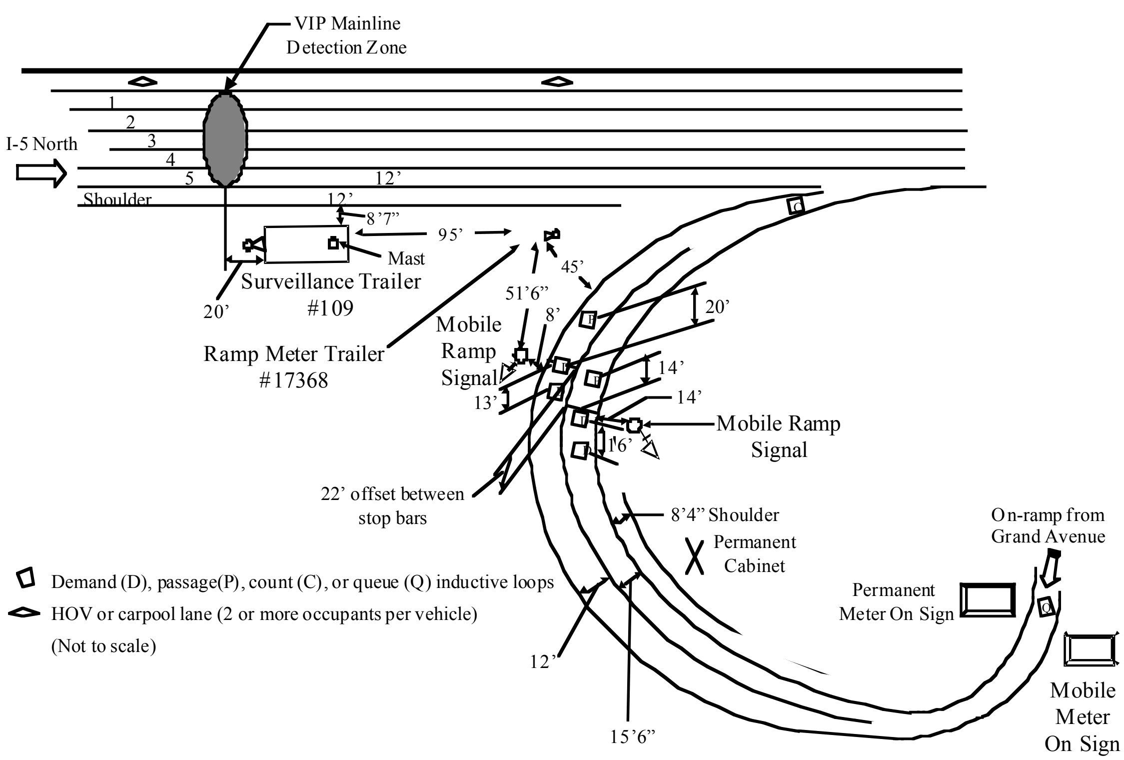


Figure 4-12. Trailer and ramp meter equipment configuration at Grand Avenue evaluation site

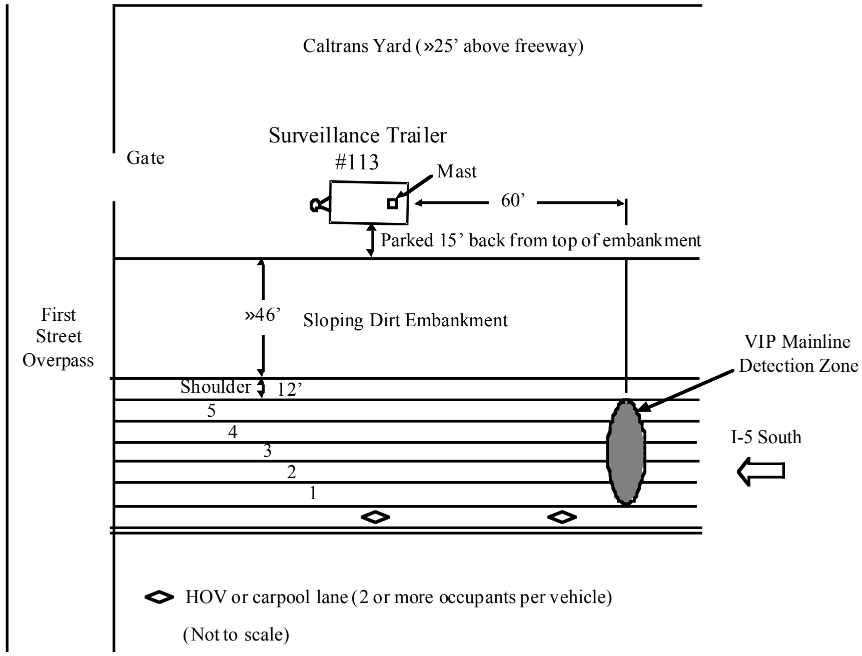


Figure 4-13. Trailer configuration at First Street evaluation site

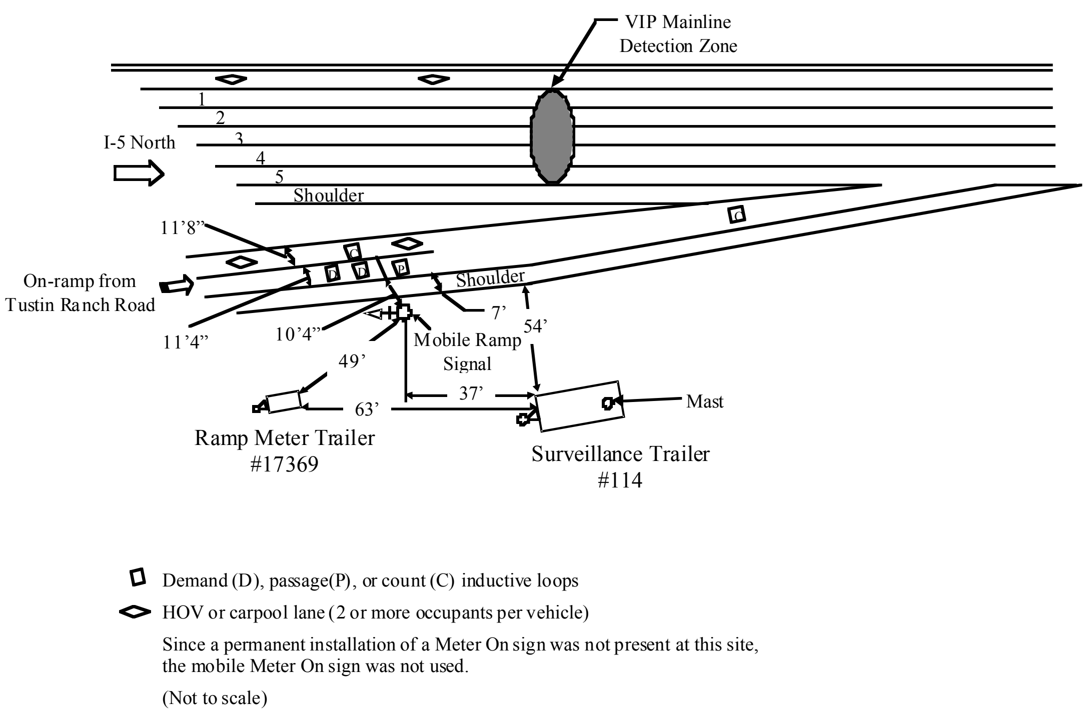


Figure 4-14. Trailer and ramp meter equipment configuration at Tustin Ranch Road evaluation site

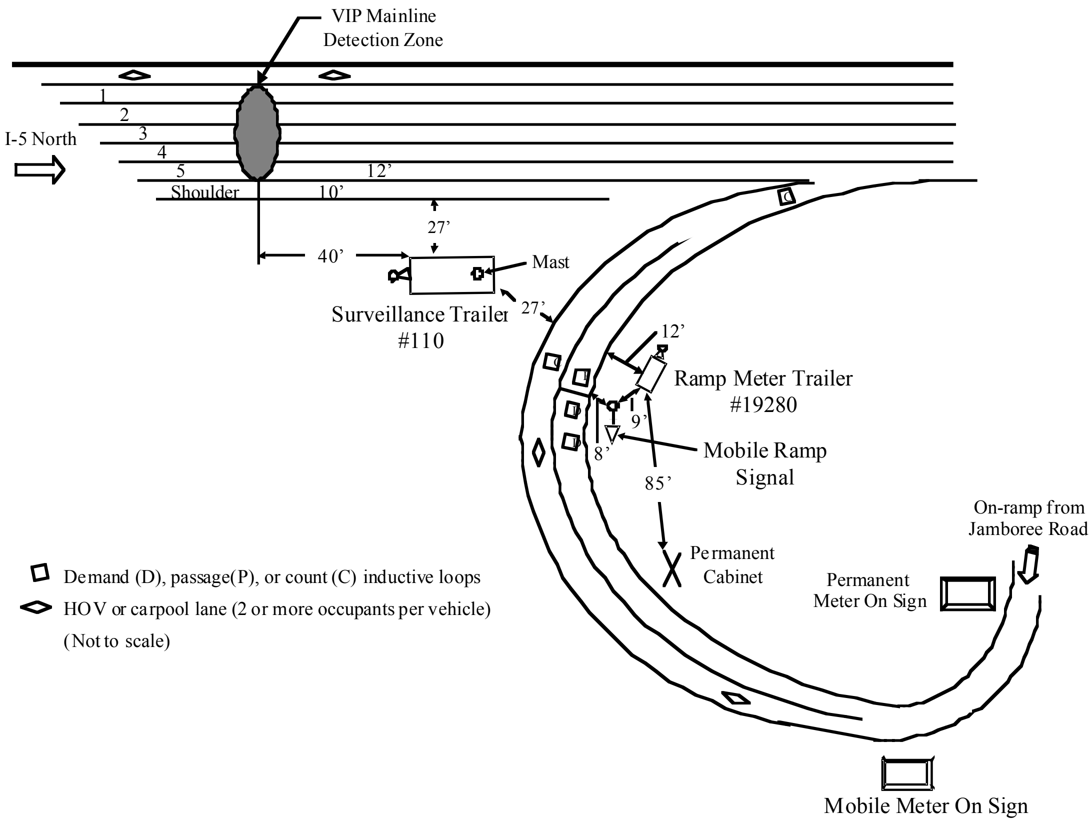


Figure 4-15. Trailer and ramp meter equipment configuration at Jamboree Road evaluation site

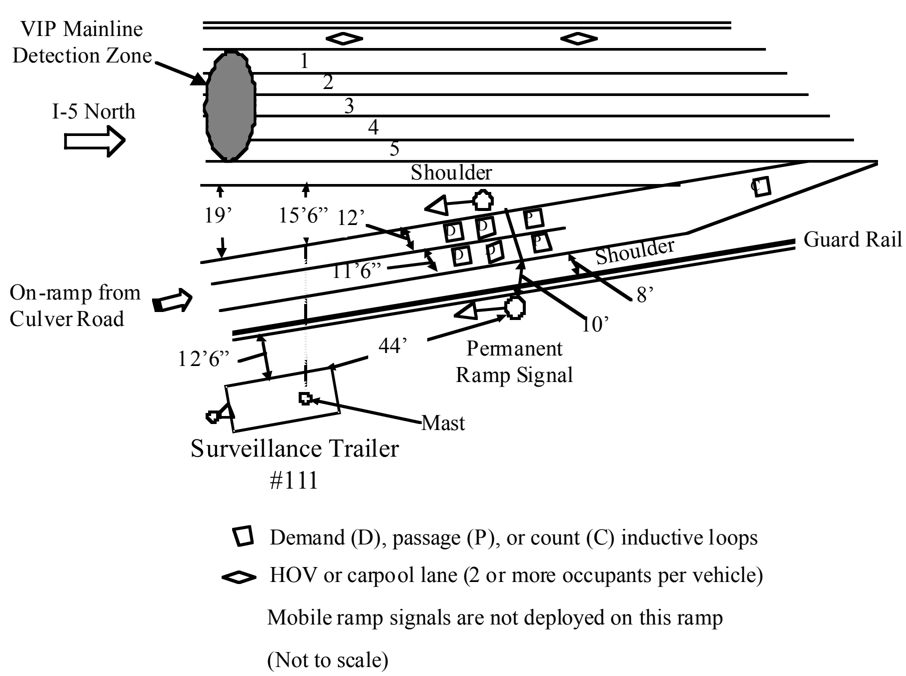


Figure 4-16. Trailer configuration at Culver Drive evaluation site

The distance of the surveillance trailer, and hence VIP camera, from the near edge of the right-most mainline lane (Lane 5) and from the near edge of the ramp (for the Grand Avenue, Tustin Ranch Road, and Jamboree Road trailers only) are listed in Table 4-3. These data may be useful in interpreting the differences obtained in the ILD- and VIP-measured traffic parameters.

Table 4-3. Distance of surveillance trailers from freeway mainline and onramps

Site	Surveillance Trailer Number	Distance of Surveillance Trailer From Mainline[4]	Distance of Surveillance Trailer From Ramp[5]
Main Place	115	≈114 feet (34.7 meters)	Not applicable
First Street	113	≈73 feet (22.3 meters)	Not applicable
Grand Avenue	109	20.6 feet (6.3 meters)	≈140 feet (42.7 meters)
Tustin Ranch Road	114	≈102 feet (31.1 meters)	65 feet (19.8 meters)
Jamboree Road	110	37 feet (11.3 meters)	27 feet (8.2 meters)
Culver Drive	111	71.5 feet (21.8 meters)	Not applicable

4.3 AutoScope Detection Zones

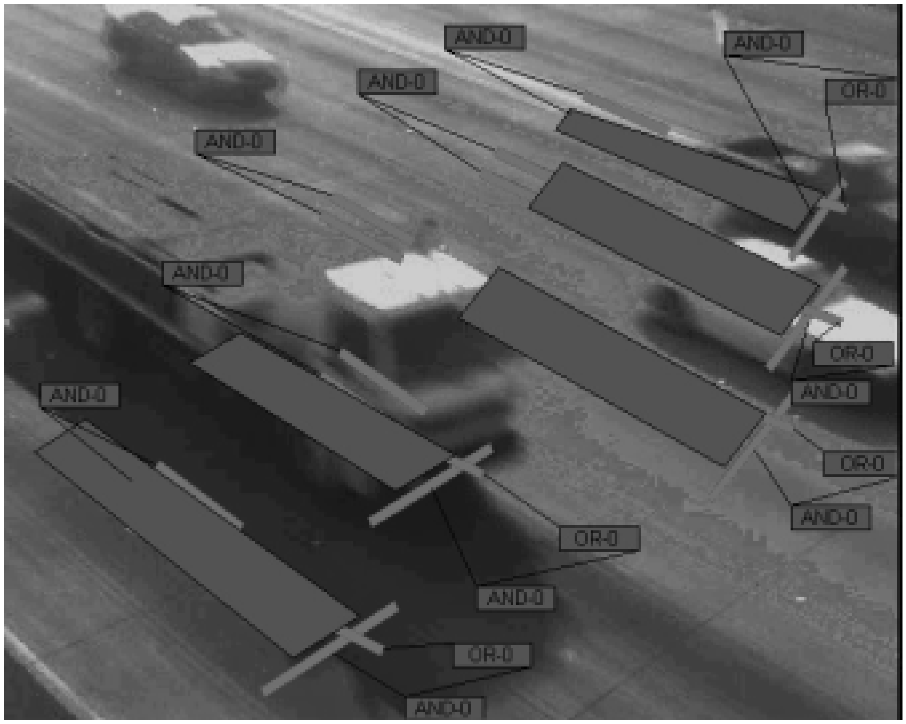
Figures 4-17 through 4-19 show the AutoScope 2004 VIP detection zones on the mainline and onramp at the three ramp meter evaluation sites. These images were downloaded from the supervisory computer used to configure the detection zones. On the mainline, count detectors were connected by AND logic to reduce false counts caused by image projection from vehicles into more than one lane. This was a noticeable problem brought on by the relatively low camera height and side-viewing geometry. Econolite placed speed (the long rectangular detection zone), presence, and demand detectors in the Grand Avenue mainline field of view to demonstrate the different options available for vehicle detection. The detectors used at Grand Avenue during the FOT are those on the left and upper portion of the image connected by AND logic. The detection zones on the ramp consisted of demand detectors. These detectors were connected by OR logic to increase the probability of vehicle detection by the VIP and the consequent change of signal from red to green. In addition to detectors parallel to traffic flow, detectors were configured in the shape of an X on the ramps to increase the probability that a vehicle was detected.

4.4 Impact of Equipment Failures on Test Schedule

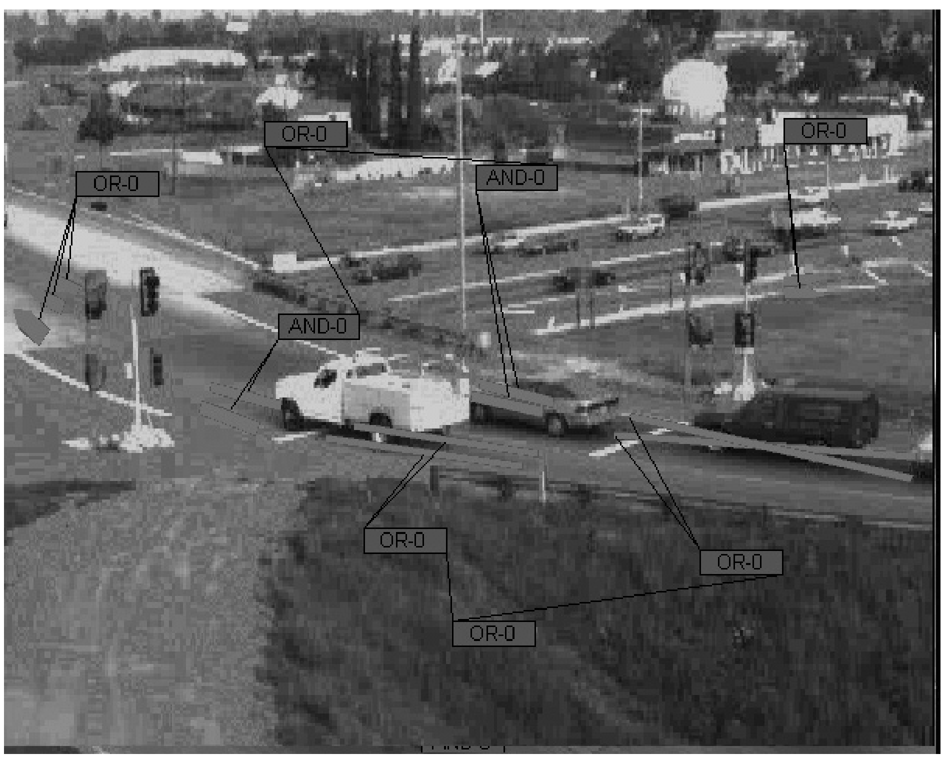
The I-5 Test was scheduled to begin Tuesday, June 17, 1997 following the completion of the System Acceptance Test (SAT). Since the SAT was postponed until November 1997, so was the start of the I-5 Test. The data to compare ILD- and VIP-measured traffic flow parameters were obtained between mid-January 1998 and May 1998.

[4]. The distance of the surveillance trailer, and hence VIP camera, from the near edge of the right-most mainline lane (Lane 5).

[5]. The distance of the surveillance trailer, and hence VIP camera, from the near edge of the ramp.

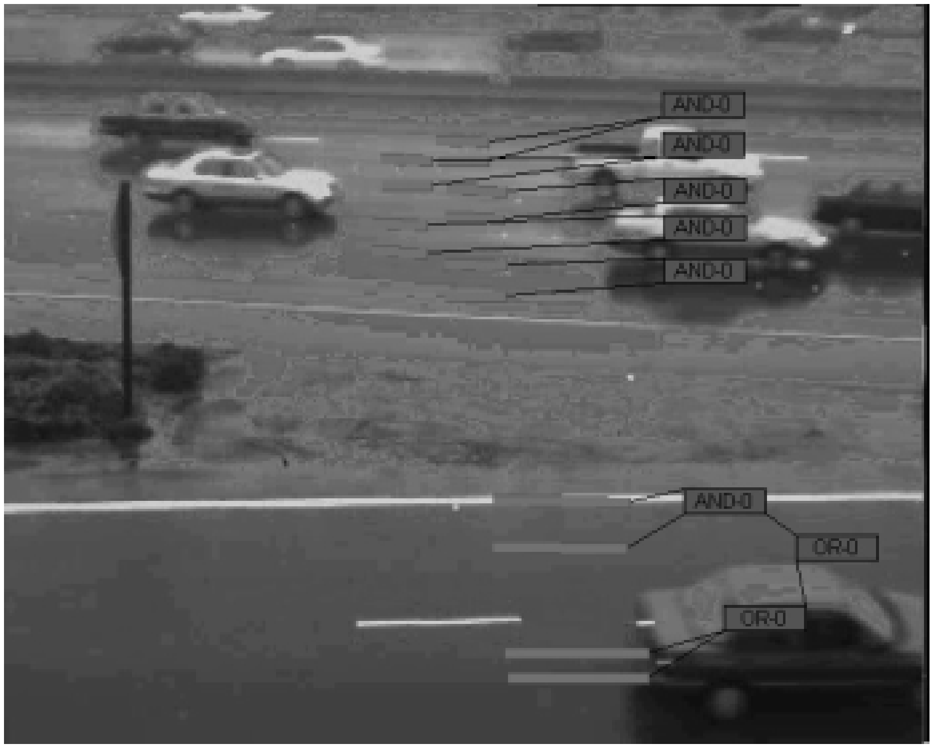


(a) Mainline detection zones

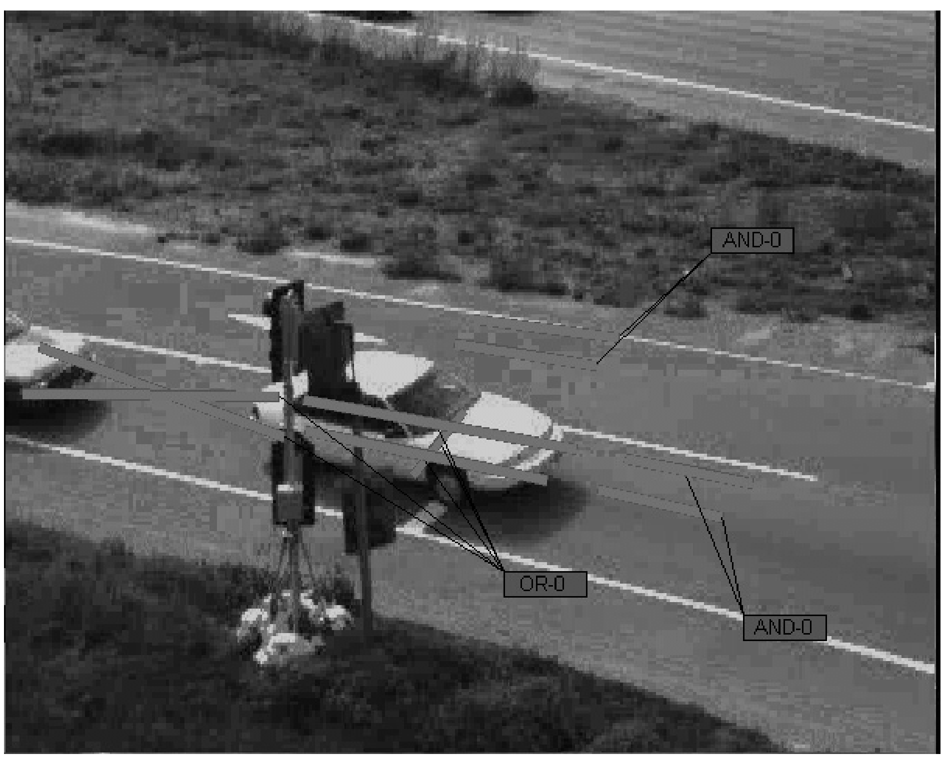


(b) Ramp detection zones

Figure 4-17. Mainline and ramp AutoScope detection zones at Grand Avenue



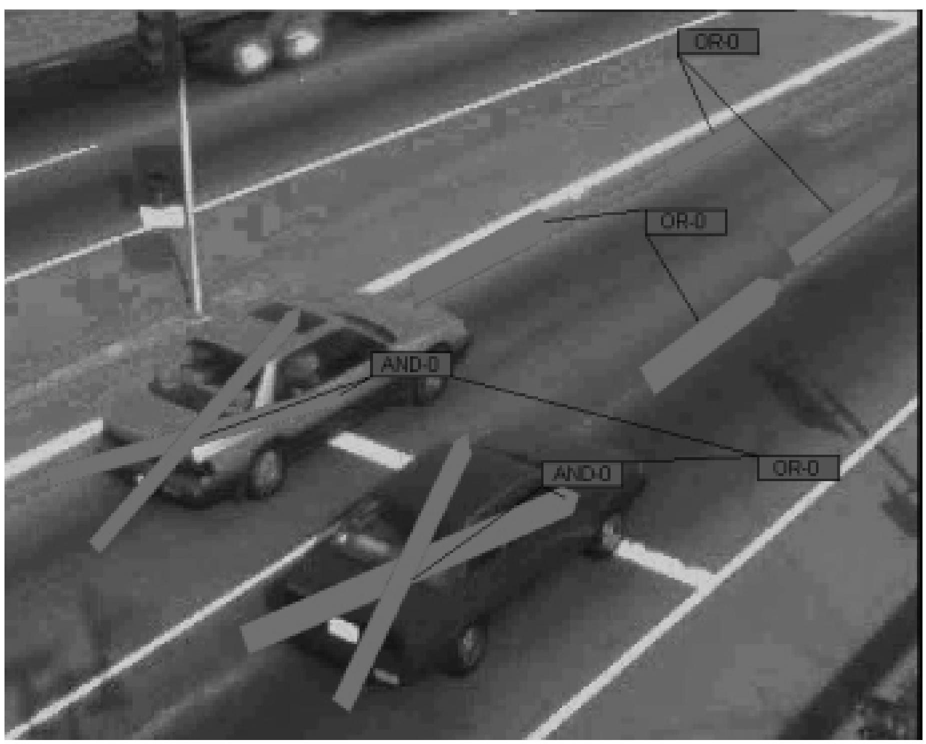
(a) Mainline detection zones



(b) Ramp detection zones

Figure 4-18. Mainline and ramp AutoScope detection zones at Tustin Ranch Road

(a) Mainline detection zones



(b) Ramp detection zones

Figure 4-19. Mainline and ramp AutoScope detection zones at Jamboree Road

Initially, several malfunctions and nonoptimal trailer operation were observed as summarized in Table 4-4. The most prevalent problem 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. Eventually, the battery voltage sensing system was redesigned and the problem abated somewhat. The Culver Drive trailer had the fewest operating problems after it was connected to public utility power. The reliability of the Culver Drive trailer supported the conclusion that the generators and portable power system, in general, were the most troublesome part of the surveillance trailer system. 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.

Two other major design flaws affected the start of the ramp trailer evaluation. The first was loss of ramp meter signal synchrony with vehicle demand on the ramp and with the synchronizing signal from the surveillance trailer. The second 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. These flaws were corrected as indicated in Table 4-4 before the tests proceeded. The failures of isolators that control the power to ramp signal bulbs delayed the test, although they were replaced with relatively minor effort.

The nonoptimal trailer operation items included excessive generator on time resulting in frequent refueling of the surveillance trailers, failure to recharge batteries that resulted in the inability to start the trailer on succeeding days, generator failure due to a faulty generator component, and low fuel level causing delay of test. These and other minor annoyances are listed in Table 4-5.

Table 4-4. Malfunctions affecting start of evaluation test and their remedies

Site	Malfunction	Remedy
Main Place Surv.Trailer	Discharged battery	Jump start; install new battery and charging circuit
	Weak data reception at TMC	Realign antenna, check electrical connections
	Generator turning off and on for short intervals	Adjust load-bank on generator. Eventually had major redesign of battery charging circuit.
First Street Surv. Trailer	Discharged battery	Jump start; replace battery
Grand Avenue Surv. Trailer	Discharged battery	Jump start; adjust load-bank on generator
	Antenna moved by winds	Realign antenna
Grand Avenue Ramp Meter Trailer	Discharged battery	Jump start; reset battery charging threshold

Table 4-4. Malfunctions affecting start of evaluation test and their remedies (continued)

Site	Malfunction	Remedy
Grand Avenue and Jamboree Road	No communications to meter-on sign	Replace AM radio transmitter and receiver with improved FM models – major effort because of trailer wiring problems
Tustin Ranch Road Surv. Trailer	Starter failed	Replace starter
Jamboree Road Surv. Trailer	Generator auto start/stop system not operating properly	Redesign auto stop/start system and software – a major effort
	Frequently found battery dead and could not start trailer	Redesign power generation and distribution system after completion of FOT – a major effort
Culver Drive Surv. Trailer	Frequently found battery dead and could not start trailer (before connecting to commercial power)	Redesign power generation and distribution system after completion of FOT – a major effort
All ramp meter trailers	Ramp meter red/green signal lost synch with ramp demand and surveillance trailer commands	Reduce data transmission rate from surveillance trailer radio transmitter to ramp meter trailer radio receiver
	Yellow signal not programmed to turn on at beginning of metering interval	Modify software so that ramp signal went from green, to extended yellow, to red at beginning of metering interval - a major effort
Tustin Ranch Road Ramp Meter Trailer	Isolator that sends power to signal bulb failed	Replace isolator
Jamboree Road Ramp Meter Trailer	Isolator that sends power to signal bulb failed	Replace isolator

Table 4-5. Annoyances with trailer performance during the I-5 Test

Site	Malfunction	Remedy
Tustin Ranch Road Surv. Trailer	Frequently oil level low, ants in trailer	Add oil, spray trailer for ants, and set ant traps
Culver Drive Surv. Trailer	Winds of 40 to 50 mph (64 to 80 km/hr) misaligned antenna	Reposition antenna for maximum signal to relay site
Culver Drive Surv. Trailer	DC to AC inverter failed	Replace inverter and blown fuse in 170 controller
All trailers	Generators either ran more frequently than desired or did not keep batteries charged	Redesign auto stop/start circuit for the generator - a major effort

4.5 Trailer Deployment and Data Collection Procedures

The process of deploying the surveillance and ramp meter trailers and collecting the evaluation data consisted of four steps, namely trailer transport, trailer setup, surveillance trailer operation, and ramp meter trailer operation. Prior experience with trailer deployment was gained during the Anaheim Special Event Test in March, April, and May 1997. A dry run of most of the I-5 Test evaluation activities occurred during the SAT on November 14, 15, and 17 1997.

Step 1. Trailer Transport

During the Anaheim Special Event Test in April 1997, surveillance trailers were moved to the three surveillance-trailer-only sites in preparation for the Systems Acceptance Test originally scheduled for June 26, 1997. Therefore, Caltrans District 12 Maintenance only needed to transport a surveillance trailer and a ramp meter trailer to the three ramp meter evaluation sites as part of the trailer transport process for the I-5 Test. The first three locations below were the sites where surveillance trailers were already in place. The last three are the sites where trailers were transported at the start of the test.

- Surveillance Trailer #115,
  Already located, Northbound I-5 at Main Place Shopping Center.

- Surveillance Trailer #113,
  Already located, Southbound I-5 at First Street.

- Surveillance Trailer #111,
  Already located, Northbound I-5 at Culver Drive.

- Moved Surveillance Trailer #110 and Ramp Meter Trailer #19280
  to Northbound I-5 at Jamboree Road.

- Moved Surveillance Trailer #114 and Ramp Meter Trailer #17369
  to Northbound I-5 at Tustin Ranch Road.

- Moved Surveillance Trailer #109 and Ramp Meter Trailer #17368
  to Northbound I-5 at Grand Avenue.

Once the trailers were deployed, they were not moved until the I-5 Test was completed in May 1988. The evaluation plan, though, did allow one of the trailers not at the ramp sites (Trailer #111, #113 or #115) to be relocated to support other research or operational activities after the initial four week evaluation period was complete.

Step 2. Trailer Setup

The trailers were set in place and checked for proper operation upon reaching the evaluation site. Caltrans was responsible for this activity with assistance from Hughes. Econolite also assisted in VIP detection zone setup and calibration.

During trailer transport and setup, data were collected to support Test Objective 1 (Examine Portability). The evaluators measured the time to complete the transport and setup tasks as recorded on data sheets shown in Appendix E. The data collection procedure is described in Section 4.6.1.4.

Step 3. Surveillance Trailer Operation

The surveillance trailers were operated at designated times to verify camera image quality and control and traffic detection via video image processing. Video image quality and camera control were monitored at the Caltrans District 12 and Anaheim TMCs. VIP data verification was planned for the District 12 TMC, the only location that could receive data. Video image quality checks were also conducted at the UCI-ITS Laboratory. Personnel were designated at each location to be responsible for gathering the required information and data. They were permitted to delegate their responsibility to another staff member after notifying the evaluators of the proposed change.

Figure 4-20 shows a District 12 TMC workstation from which camera control, image quality checks, and data acquisition could occur.

Figure 4-20. Caltrans District 12 workstation displaying camera selection icons on the left monitor

Camera control and image quality were checked more frequently on the first day of the test, when "Hourly" checks occurred at the District 12 TMC beginning at 6:00 a.m. Each camera control function and image was monitored approximately every hour until about 3 p.m. At the Anaheim TMC, beginning at 9:00 a.m. on the first day, each camera image and each camera control were checked every two hours for the eight hour period ending at 5:00 p.m. For the UCI-ITS Laboratory, beginning at 12:00 noon on the first day, each camera image was to be checked every three hours for one six hour period (ending at 6:00 p.m.). The schedule was designed to simultaneously share equipment use among two and three locations and uncover any problems that might arise. In fact, it soon became apparent that there was a conflict in the simultaneous reception of video imagery at Anaheim and UCI. Whenever one of these sites had the SSR video receiver on, the other could not receive imagery. Since it was inconvenient to turn the receiver at UCI on and off several times a day (as it was located on a roof with controlled access), it was left off for most of the test. Towards the end of the testing period, a remote switch was installed at UCI so that the video SSR receiver could be turned off from the fifth floor ITS transportation laboratory. Video image reception was verified at UCI on two occasions, one during the SAT and one towards the end of the I-5 Test after the switch was installed and Anaheim had been instructed to turn their receiver off.

The frequency of camera control and image quality data collection at the District 12 TMC was reduced to three times a day on the second through fourteenth days of testing. Data on these days were acquired in early morning, noon, and in the afternoon. Three days of once to twice-a-day testing followed, with data acquisition in the early morning or early morning and afternoon. Anaheim followed a similar schedule.

The Automated Traffic Management System at District 12 was checked for VIP and ILD data four times in the morning and three times during the afternoon of the first day of testing. Over the next five days of testing, the ATMS was interrogated one to four times a day in an attempt to retrieve VIP and ILD data. At best, the ILD data were updated in an inconsistent manner and the VIP data did not appear at all. Discussions were held with the contractor who developed the ATMS software and with Hughes concerning these problems. Attempts were made to remedy the problems, but the data remained unavailable from the ATMS for the duration of the FOT.

Since the start of data acquisition for the I-5 Test was delayed by almost a year (Spring 1997 to Spring 1998), there was not enough time to gather data on a weekly and monthly schedule. Problems with synchronizing commands from the surveillance trailer to the ramp meter trailer, a software modification to incorporate a long yellow signal in the ramp meter turnon sequence, frequent power system failures in the trailers, and the inability of the District 12 ATMS to poll the 170 controllers attached to the VIPs subjected the data acquisition schedule to additional delays. As a result, only about two and a half days of quantitative data, comparing ILD- and VIP-measured traffic volumes and lane occupancies, were obtained at each of the ramp meter sites during Spring 1998. Data concerning camera control and image quality were obtained over a longer time interval as these activities could proceed in the presence of some of the above problems.

The cameras in each trailer were checked in sequence starting with Camera #1 (mainline VIP) image and data, Camera #2 (onramp VIP) image and data, Camera #3 (surveillance only) image and camera pan, tilt, zoom control, and Camera #4 (security). The results were recorded on the Camera Operability and VIP Believability Data Sheets provided by the evaluator (as shown in Appendices D and E). The evaluator coordinated and assisted with the data collection activity. The same data sheets were used to note any problems uncovered during the test. The associated data collection procedure is described in Section 4.2.2.4. As the mainline and ramp data produced by the VIPs were not being displayed on the District 12 ATMS, the VIP Believability data collection was discontinued after the sixth day.

Independent of the scheduled checks, the surveillance trailers at each evaluation site could be turned on as needed for location-specific traffic monitoring or research activities. Each time a surveillance trailer was used for real-time traffic management or as part of a technology demonstration, the responsible party was to record the date, time, event type, problems encountered, and any coordination required between the District 12 TMC, Anaheim TMC, and UCI-ITS Laboratory.

Step 4. Ramp Meter Trailer Operation

The surveillance and ramp meter trailers at each ramp meter site were turned on and off at the beginning and end of the ramp-metering periods to conserve fuel. When metering, the ramp meter trailers transmitted the metering rates received from the surveillance trailers to the ramp signals that regulated traffic from the onramp onto the mainline of the freeway. The ramp-metering period was scheduled in the morning from 06:00 hours until 09:30 hours. In the afternoon, the metering period was from 15:00 hours until 19:00 hours. The original ramp meter rates were the same as those in the time-of-day table stored in the 170 controller at the evaluation site.

The primary ramp meter functionality checks and data acquisition were performed at the ramp meter locations. Ramp meter data were also supposed to be available at the District 12 TMC. However, with the failure of the ATMS to display the 170 controller data captured from the VIPs and its inconsistent updating of the ILD data, we relied exclusively on data collected at the evaluation sites. Caltrans was responsible for performing the primary ramp meter checks with assistance of the evaluator. TMC personnel were responsible for the camera control and image quality checks.

Ramp meter functionality was checked more frequently early in the test. When the test began, the evaluators remained at the sites for several hours to ensure that the ramp signals were changing in synchronization with vehicle demand and surveillance trailer commands. Once the equipment was functioning without problems, the original evaluation plan specified that data acquisition begin at 06:00 hours on the first day, with “Hourly” checks of ramp meter functionality. Data acquisition continued for the duration of the a.m. traffic period (ending at 09:30 hours). During the afternoon peak period, beginning at 15:00 hours, each ramp meter site was checked every hour for the duration of the p.m. peak period (ending at 19:00 hours). In fact, what occurred in the field was the continuous recording of ILD and VIP data on laptop computers for the duration of the morning and afternoon rush hour periods. The synchronization of vehicle demand and signal response was also verified hourly.

The frequency at which the mobile ramp metering was checked was to be reduced from hourly to daily to weekly to monthly. Because of the delays in starting the test, only the hourly schedule was utilized.

Because the ATMS could not display the 170 controller data captured form the VIPs, each ramp site was evaluated separately, rather than concurrently. This procedure was used because two laptop computers were needed at each site to record data and only two computers were available. In the field, Caltrans and the evaluator checked that all equipment, including the ramp meter-on sign, was in the proper state and that vehicle presence and passage were properly detected. Vehicle presence detection was verified by noting if the ramp signal alternated between green and red when vehicles were present, and if the signal remained red when vehicles were not present. Ramp queue overflow detection was checked by recording the times when the ramp queue extended beyond the start of the onramp. This event was only detectable by the ILDs since the VIP camera was aimed at the end of the ramp, near the signal, and not the start of the ramp where queue overflow would occur.

Caltrans recorded the results of these checks on the Ramp Meter Operability Data Sheets provided by the evaluator (see Appendix H). The same data sheets were used to note any problems uncovered during the test. More detailed descriptions of the associated data collection procedures are given in Section 4.6.2.9.

4.6 Evaluation Results

Several of the tasks in the I-5 Test Evaluation Plan could not be performed because the data needed were not available. These instances are noted. Some test evaluation data dealing the trailer portability were collected in April and June 1997 when trailers were set in place for the SAT. These trailer transport data sheets are included in Appendix E.

4.6.1 Test Objective 1 - Portability

The objective of the portability evaluation was to assess the ease with which the surveillance and ramp meter trailers were moved into the field, setup, and made operational in support of the I-5 Test.

4.6.1.1 Measures of Performance

The measures of performance for this assessment are:

- Measure 1.1: Pre-transport preparations
- Measure 1.2: Time to hitch, transport, setup, make operational
- Measure 1.3: Transport and setup obstacles, problems, and remedies.

4.6.1.2 Test Data

The data collected in support of each performance measure are:

Measure 1.1: Pre-transport preparations

Data 1.1.1: Identity of pre-transport preparations

Data 1.1.2: Level-of-effort for pre-transport preparations

Measure 1.2: Time to hitch, transport, setup, and make operational

Data 1.2.1: Number of minutes to hitch surveillance trailer

Data 1.2.2: Number of minutes to transport surveillance trailer

Data 1.2.3: Number of minutes to setup surveillance trailer

Data 1.2.4: Number of minutes to hitch ramp meter trailer

Data 1.2.5: Number of minutes to transport ramp meter trailer

Data 1.2.6: Number of minutes to setup ramp meter trailer

Data 1.2.7: Number of minutes to make trailer set operational

Measure 1.3: Transport and setup obstacles, problems, and remedies

Data 1.3.1: Identity of transport and setup obstacles, problems, and remedies

Data 1.3.2: Severity of transport obstacles, problems, and remedies

4.6.1.3 Data Collection Procedures for Performance Measure 1.1

The procedures for collecting the data in support of Objective 1 are described below.

Data 1.1.1: Identity of pre-transport preparations

Panning for the trailer deployment planning occurred over many months, resulting in a list of pre-transport preparation topics. The topics are:

Preparation 1: Site Selection

Preparation 2: Site Survey

Preparation 3: Site Readiness

Preparation 4: Trailer Readiness

The evaluator requested written statements from Caltrans confirming that this list was complete in that it correctly identified each pre-transport preparation topic. The result of this activity was Data 1.1.1, the identity of pre-transport preparation items.

Data 1.1.2: Level-of-effort for pre-transport preparations

The pre-transport preparations for the I-5 Test were similar to those encountered for the Anaheim Special Event Test as reported earlier. There was not any new information in the form of statements from the PMT members that addressed specific I–5 Test pre-transport preparations. Rather, problems and their solutions were noted by annotating the Trailer Transport Data Sheets and surveillance trailer and ramp meter trailer logs. The information that addresses the impact of trailer readiness on the test schedule has been presented in Tables 4-4 and 4-5 of Section 4.3.

4.6.1.4 Data Collection Procedures for Performance Measure 1.2

The methods for collecting the data associated with Performance Measure 1.2 (time to hitch, transport, set in place, and make operational) are identical. Thus, these data items are covered concurrently in this section.

- **Data 1.2.1: Number of minutes to hitch surveillance trailer**
- **Data 1.2.2: Number of minutes to transport surveillance trailer**
- **Data 1.2.3: Number of minutes to set in place surveillance trailer**
- **Data 1.2.4: Number of minutes to hitch ramp meter trailer**
- **Data 1.2.5: Number of minutes to transport ramp meter trailer**
- **Data 1.2.6: Number of minutes to set in place ramp meter trailer**
- **Data 1.2.7: Number of minutes to make trailer pair operational**

The evaluator observed each trailer transport event and coordinated the collection of test data. The evaluator was contacted by Caltrans to confirm the departure point and start time no less than 24 hours prior to each scheduled trailer transport event. The departure point was the current location of the trailer to be transported. The start time was the time the transport crew arrived at the departure point.

The evaluator arrived at the departure point at least 10 minutes prior to the start time with a watch and a Trailer Transport Data Sheet that contained six columns including one for comments. Appendix E contains the Trailer Transport Data Sheets used to record the time of the transportation milestones. The milestones were "Began", " Hitched", " Arrived", "Set in Place", and “Departed”. Separate sheets were used for the surveillance and ramp meter trailers. When the Caltrans transportation crew was ready to begin towing operations (i.e., raising outriggers, lowering mast, reorienting cameras and antenna, making trailer mechanical and electrical connections, etc.), that time was recorded in the "Began" field. When the trailer was hitched and ready to transport, that time was recorded in the " Hitched" field. When the trailer arrived at the destination site, that time was recorded in the "Arrived" column. When the trailer was set in place (i.e., in its final location with the trailer level, outriggers extended, and wheels chocked) so that checkout could proceed, that time was recorded in the "Set" field. The time when the tow truck and crew departed the test site (with the trailer operational) was written in the “Departed” field. When two trailers were moved at the same time, two tow trucks and two crews were used, and the corresponding times for each trailer were entered on datasheets designated for each of the surveillance and ramp meter trailers. Throughout the transport and setup process, any observed problems and obstacles were noted in Column 6 reserved for comments.

Data 1.2.1, the number of minutes to hitch a surveillance trailer, was computed as the difference between the "Began" time and the "Hitched" time.

Data 1.2.2, the number of minutes to transport a surveillance trailer, was computed as the difference between the "Hitched" time and the "Arrived" time.

Data 1.2.3, the number of minutes to set a surveillance trailer in place, was computed as the difference between the "Arrived" time and the "Set" time.

Data 1.2.4, the number of minutes to hitch a ramp meter trailer, was computed as the difference between the "Set" time and the "Hitched" time.

Data 1.2.5, the number of minutes to transport a ramp meter trailer, was computed as the difference between the "Hitched" time and the "Arrived" time.

Data 1.2.6, the number of minutes to set a ramp meter trailer in place, was computed as the difference between the "Arrived" time and the "Set" time.

Data 1.2.7, the number of minutes to make the trailer combination operational, was computed for each surveillance trailer-ramp meter trailer set as the time difference between the "Ramp Meter Set" time and the "Depart" time, or the “Surveillance Trailer Set” time and the "Depart" time, whichever gave the larger interval.

The evaluator recorded the data; calculated the hitch, transport, set in place, and make operational times; and summarized the results as shown in Tables 4-6 and 4-7. 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. As found in the Anaheim Special Event Test, the transport times were a function of the distance traveled to the evaluation site. 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.

Table 4-6. Trailer hitch, arrived, set, and departed data

Destin-ation	Move Date	Trailer Number	Began	Hitched	Arrived	Set	Departed	Comments
I-5 at Culver Drive	4/10/97	111 (Surv.)	8:09am	8:24am 8:55am	8:45am 9:12am	9:17am	9:27am*	Add air to tires at Caltrans yard; another

								commitment prevented completion of checkout
I-5 at First Street	4/10/97	113 (Surv.)	9:42am	9:50am	≈10:10am 10:27am	10:32am	10:49am	Add air to tires at Caltrans yard
I-5 at Main Place	4/10/97	115 (Surv.)	11:05am	11:14am	11:40am	11:45am	12:40pm	Color bar noise on video received at Anaheim TMC
I-5 at Jamb-oree Road	6/3/97	110 (Surv.)	9:27am	9:52am 10:15am	10:55am	11:13am	1:10pm	Delay leaving Hughes lot: trailer lights not working and washed trailers
I-5 at Jamb-oree Road	6/3/97	19280 (Ramp)	9:09am	9:15am 10:15am	11:17am	11:34am	1:10pm	Departed before ramp meter signal sequence was verified
I-5 at Grand Ave.	6/14/97	109 (Surv.)	5:48am	6:09am 7:18am	7:50am	8:55am	12:30pm	Delay leaving Hughes lot: Searched for D-clamps, pumped tires, and washed trailers

Table 4-6. Trailer hitch, arrived, set, and departed data (continued)

Destin-ation	Move Date	Trailer Number	Began	Hitched	Arrived	Set	Departed	Comments
I-5 at Grand Ave.	6/14/97	17368 (Ramp)	6:00am	6:15am 7:18am	7:50am	9:42am	---	Ramp meter signal sequence not verified; meter-on sign not working
I-5 at Tustin Ranch Road	6/18/97	114 (Surv.)	7:20am	7:35am 8:05am	9:00am	11:10am	2:40pm (Includes 1-hr lunch break)	Washed trailers before leaving lot; re-examined site for best trailer location
I-5 at Tustin Ranch Road	6/18/97	17369 (Ramp)	7:20am	7:35am 8:05am	9:00am	10:45am	11:00am	Washed trailers before leaving lot

* Checkout not completed for reasons stated in the table. Therefore, the time to make the trailer operational could not be calculated for this data set.

Table 4-7. Hitch, transport, set in place, and make operational times

Destination	Trailer Move Date	Trailer Number	Hitch Time (min)	Transport Time (min)	Set in Place Time (min)	Make Operational Time (min)
Culver Drive	4/10/97	111	15	21	—	—
Culver Drive	4/10/97	111	—	17	5	*
First Street	4/10/97	113	8	20	5	17
Main Place	4/10/97	115	9	26	5	55
Jamboree Rd.	6/3/97	110	25	40	18	117
Jamboree Rd.	6/3/97	19280	6	62	17	—
Grand Ave.	6/14/97	109	21	32	65	215
Grand Ave.	6/14/97	17368	15	32	112	—
Tustin Ranch Rd.	6/18/97	114	15	55	130	175
Tustin Ranch Rd.	6/18/97	17369	15	55	105	—
Mean			14	36	51	116
Std. Deviation			7	15	49	73

* Checkout not completed for reasons stated in Table 3-1.

The moderately large time for Trailer 115 at Main Place to become operational was due to the weak signal received at the Anaheim TMC. Extra time was required for moving the trailer to a potentially better location and realigning the trailer antenna to improve the signal strength. At this point in the evaluation, none of the ramp meter signals was reliable. Either they immediately failed to synchronize with vehicle demand or commands from the surveillance trailer, or they lost synchronization after several minutes. It was not until after the SAT that this problem was isolated and fixed by lowering the transmission rate of the commands from the surveillance trailer to the ramp meter trailer.

4.6.1.5 Data Collection Procedures for Performance Measure 1.3

This section contains the data collection procedures for Performance Measure 1.3, transport and setup obstacles, problems, and remedies.

Data 1.3.1: Identity of transport and setup obstacles, problems, and remedies

Trailer transport activities for the I-5 Test were completed June 18, 1997. Based on the transport activities, the evaluator compiled a list of transport and setup problems, obstacles, and remedies from entries on the Trailer Transport Data Sheets and the logs kept in each surveillance trailer. The result of this activity was Data 1.3.1, the identity of transport and setup obstacles, problems, and remedies. These data have already appeared in Tables 4-4 and 4-5 of Section 4.4.

Data 1.3.2: Severity of transport obstacles, problems, and remedies

When information about the severity of the transport obstacles, problems, and remedies was provided to the evaluator, it was incorporated into Data Item 1.3.1 as indicated in Tables 4-4 and 4-5.

4.6.2 Test Objective 2 - Effectiveness of Trailers for Traffic Management

The objective developed for determining the effectiveness of the trailers for traffic management had three parts. The first was to determine if the video imagery provided by the surveillance trailers was suitable for viewing freeway traffic. The second was to determine if the data provided by the surveillance trailers were suitable for assessing freeway traffic flow parameters. The third was to determine if the ramp meter trailers were suitable for metering traffic from freeway onramps onto freeway mainlines.

4.6.2.1 Measures of Performance

The measures of performance for this assessment are:

- Measure 2.1: Camera image and control availability
- Measure 2.2: Camera image and control problems
- Measure 2.3: VIP data availability
- Measure 2.4: VIP data believability
- Measure 2.5: Ramp meter on/off functionality
- Measure 2.6: Ramp meter vehicle presence treatment

- Measure 2.7: Ramp meter problems.

4.6.2.2 Test Data

The data collected in support of each performance measure are:

Measure 2.1: Camera image and control availability

Data 2.1.1: Camera image percent up time

Data 2.1.2: Camera control percent up time

Measure 2.2: Camera image and control problems

Data 2.2.1: Identity of camera image and control problems

Measure 2.3: VIP data availability

Data 2.3.1: VIP percent up time

Measure 2.4: VIP data believability

Data 2.4.1: Percent VIP data match video assessment

Measure 2.5: Ramp meter on/off functionality

Data 2.5.1: Percent ramp signal correctly powered on/off

Data 2.5.2: Percent meter-on sign correctly powered on/off

Measure 2.6: Ramp meter presence treatment

Data 2.6.1: Percent proper vehicle presence response

Measure 2.7: Ramp meter problems

Data 2.7.1: Identity of ramp meter problems

4.6.2.3 Data Collection Training

The evaluation staff was trained in the data collection procedures no sooner than one week before data collection began so that the procedures could be easily recalled. Training included visits to the trailers, TMCs, and UCI-ITS Laboratory, as needed.

4.6.2.4 Data Collection Procedures for Performance Measure 2.1

Data 2.1.1 and Data 2.1.2 were gathered concurrently and thus are described together.

Data 2.1.1: Camera image percent up time

Data 2.1.2: Camera control percent up time

Several evaluators were involved in the first stages of collecting data for this performance measure. The multiple evaluator phase lasted about one week. One evaluator observed camera image quality, camera control, and VIP data believability checks and coordinated the collection of test data at the District 12 TMC. A second evaluator performed similar functions at the Anaheim TMC, and a third at the UCI-ITS Laboratory.

The evaluators delivered sets of six Camera Operability Data Sheets (as shown in Appendix F) to the TMCs and UCI. Each data sheet in a set was for a different surveillance trailer. The District 12 and Anaheim TMCs were given loose-leaf books that contained multiple sets of data sheets separated by tabs to divide the hourly, daily, weekly, and monthly entries. Each data sheet contained two parts: Part I for prescribed camera image and control checks and Part II for notes. Part I contained nine columns: Column 1 for time of data entry; Column 2 for operator's initials; Column 3 for Mainline VIP Camera Image; Column 4 for Onramp VIP Camera Image; Column 5 for Surveillance Camera Image; Columns 6-8 for Surveillance Camera Control of Pan, Tilt, and Zoom; and Column 9 for Security Camera Image.

At each check, one row was completed on all six data sheets. For each camera image verification, a "check" mark (√) was placed in the corresponding data sheet cell if the camera image was available; otherwise an "x" mark was recorded in the cell. For each camera control verification, a "check" mark (√) was placed in the corresponding cell if the pan, tilt, and zoom for the color surveillance camera was operating. If one or more of the camera controls were not working, an "x" mark was recorded.

Data 2.1.1, camera image percent up time, was to be computed for each camera and for each location as the ratio of image "up" time to total time (sum of image "up" plus image "down" time). A check mark in a Camera Image Column was interpreted to mean that the associated camera image was present for the entire duration since the last check. An "x" mark in Camera Image Column was interpreted to mean that the associated camera image was "down" for the entire duration since the last check.

Data 2.1.2, camera control percent up time, was to be computed for each pan, tilt, and zoom control at each location. The camera control percent up time was defined as the ratio of control "up" time to total time (sum of "up" plus "down" time). A check mark in a Camera Control Column was interpreted to mean that pan, tilt, and zoom controls were operating for the entire duration since the last check. An "x" mark in a Camera Control Column was interpreted to mean that the camera control was not operational for the entire duration since the last check.

4.6.2.5 Data Collection Procedures for Performance Measure 2.2

Data 2.2.1 supports Performance Measure 2.2, camera image and control problems.

Data 2.2.1: Identity of camera image and control problems

Part II of each data sheet contained 20 numbered lines. When the first "x" mark was placed on Part I of the data sheet, a written statement was entered on Line 1 of Part II of the data sheet. This statement explained the nature of the problem associated with the first "x" mark denoted by “x1”. When the second "x" mark (reading from left to right and top to bottom) was placed on Part I of the data sheet, a written statement was entered on Line 2 of Part II of the data sheet. The second written statement explained the problem associated with the second "x" mark denoted by “x2”. The process continued with a note written for each "x" entry. These notes provided Data 2.2.1, identity of camera image and control problems.

4.6.2.6 Results from Data Gathered in Support of Performance Measures 2.1 and 2.2

The lessons learned from the data acquired at the TMCs in support of Performance Measures 2.1 and 2.2 are summarized as:

- Once the cameras and communications links were operational, camera control and picture quality were consistent from each venue. The camera control keyboard and other electronic assemblies used to control and select cameras appeared stable. Exceptions occurred when strong winds moved the antennas or the mast accidentally dropped because the locking pins were not fully extended.
- The transmission link should be checked over several days to ensure that the imagery is consistently good and relatively unaffected by weather and blowing trees.
- During periods of high winds, the antenna may move, thereby reducing signal to the relay site. In this case, realignment of the antenna is required.
- If the pins that lock the mast sections in place are not fully extended, several sections of the mast can fall and alter the field of view and calibration of the VIP.
- The stops on the surveillance camera should be adjusted during trailer setup to ensure that the camera can rotate to provide imagery of 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 assembly for the surveillance camera should be upgraded to a model that can support more weight. The manufacturer changed his specifications once the assembly was purchased and installed, and it was no longer recommended for the weight posed by the camera and all-weather enclosure. Therefore, the surveillance camera should not be tilted lower than the position necessary for horizontal viewing. If this limit is exceeded, it will not be possible to remotely raise the camera. In this event, the trailer mast will have to be lowered and the camera raised manually. Since the mast is moved in this procedure, the VIP camera alignment and calibration will also have to be verified.
- The sun shields should be extended to prevent glare at sunrise and sunset.
- To prevent vandalism to the security camera’s video and power cables, the cables should be protected, e.g., by placing them in conduit.

- The focus and f-stop on the security cameras have to be adjusted for optimum day and night use.
- At times, the graphical user interface (GUI) at the Caltrans ATMS stations failed to provide camera control. Control was still available, however, from the keyboard in the equipment rack located in the back room of the TMC.

4.6.2.7 Data Collection Procedures for Performance Measures 2.3 and 2.4

Data 2.3.1 and Data 2.4.1 were to be gathered concurrently in support of Performance Measures 2.3 and 2.4 and thus are described together.

Data 2.3.1: VIP percent up time

Data 2.4.1: Percent VIP data match video assessment

The evaluator also delivered sets of six VIP Believability Data Sheets (as shown in Appendix G), one for each of the six surveillance trailers, to the District 12 TMC. These data sheets were placed in the loose-leaf binder at the TMC. The data sheets contained two parts: Part I for prescribed VIP believability checks and Part II for notes. Part I contained eight columns: Column 1 for time of data entry; Column 2 for operator's initials; Column 3 for Mainline Loop ATMS 5-minute Averaged Volume, Occupancy, and Speed Data; Column 4 for Mainline VIP ATMS 5-minute Averaged Volume, Occupancy, and Speed Data; Column 5 for Mainline VIP Data Correspond to Visual Check of Volume, Occupancy, and Speed; Column 6 for Onramp Loop ATMS 5-min Averaged Data Entries of Demand, Passage, and Overflow; Column 7 for Onramp VIP ATMS 5-min Averaged Data Entries of Demand and Passage; and Column 8 for Onramp VIP Data Correspond to Visual Check of Demand and Passage.

One row on the Part I data sheet was to be used for each VIP check. For each data item requiring a numerical entry, a number was placed in the corresponding cell if the loop or VIP data were available. The Column 5 entry for VIP data correspondence to visual imagery simply required a "check" mark (√) if the data appeared consistent with the imagery; otherwise an "x" mark was recorded in this cell. The designated TMC operator determined whether the data were consistent with the imagery by answering the question: "If the VIP data were the only input available (no video), does it appear that the TMC would have reasonably accurate information to assess traffic conditions?" If the answer is "yes", a "check" (√) mark was placed in the Column 5. If the answer was "no", an "x" mark was entered. Problems were noted on Part II of the data sheet as before.

4.6.2.8 Results from Data Gathered in Support of Performance Measures 2.3 and 2.4

It soon became apparent that only three of the surveillance trailers were being polled by the ATMS, and even then, the polling was inconsistent. Therefore, performance measures 2.3 and 2.4 could not be recorded as originally envisioned. Instead, the technique of using two laptop computers connected directly to the 170 controllers in the surveillance trailers and roadside cabinets was used to compare ILD and VIP data. The laptop computers were used only at the three ramp meter evaluation sites. The VIP Believability Data Sheets were not used at the Anaheim or UCI-ITS Laboratory because data could not be received at these facilities.

VIP Percent Up Time (Data 2.3.1) – The percent of time that VIP data were observable at the District 12 TMC was low, approaching zero, because of the polling problem described above. However, observations from the evaluator and Caltrans confirm the VIP and its associated data were available 100 percent of the time at the surveillance trailers the field.

Percent VIP Data Match Video Assessment (Data 2.4.1) – The percent of match between freeway levels of service based on VIP data and video imagery could not be determined because VIP data were not received at the TMC. Instead, the two laptop computers were used to poll and record relevant ILD- and VIP-measured traffic flow parameters as described in Section 4.8.

4.6.2.9 Data Collection Procedures for Performance Measures 2.5 and 2.6

Data 2.5.1, Data 2.5.2, and Data 2.6.1 are gathered concurrently in support of Performance Measures 2.5 and 2.6 and thus are described together.

Data 2.5.1: Percent ramp signal correctly powered on/off

Data 2.5.2: Percent meter-on sign correctly powered on/off

Data 2.6.1: Percent proper vehicle presence response

The evaluator observed the operation of the ramp meter signals and coordinated the collection of test data. The evaluator and Caltrans personnel began ramp meter data collection at Tustin Ranch Road for a three day period and then proceeded to Jamboree Road for a similar time and finally to Grand Avenue. Originally, additional data collection was scheduled for each site. However, the time needed to identify and fix the early signal synchronization, yellow light at ramp turnon, and power system reliability problems shortened the time available for data collection.

Ramp Meter Operability Data Sheets (shown in Appendix H) were used to record information about the operation of the portable ramp meters. Each data sheet contained two parts: Part I for prescribed information and Part II for descriptions of any problems that arose. Part I contained seven columns: Column 1 for time of data entry, Column 2 for the operator’s initials, Column 3 for Ramp Meter Signal On/Off Verification, Column 4 for Ramp Meter-on Sign On/Off Verification, Column 5 for Vehicle Present Treatment Confirmed, Column 6 for Vehicle Absent Treatment Confirmed, and Column 7 to note Visual Ramp Overflow.

One row was completed for each ramp meter check. For each power on/off verification within the ramp-metering period, the word “on” was placed in the corresponding cell if the designated item was turned on; otherwise an "x" mark was entered. Outside of the scheduled ramp meter period, the ramp signals and meter-on sign were to be off.

For each vehicle presence verification, a “check” (√) mark was placed in a cell in Column 5 if the signal head alternated between green and red when vehicles were present. Otherwise, an "x" mark was entered. For each vehicle absent verification, a “check” (√) mark was placed in a cell in Column 6 if the signal head remained red when vehicles were absent. If the signal did not remain red, an "x" mark was entered.

Percent ramp signal correctly powered on/off (Data 2.5.1) and percent meter-on sign correctly powered on/off (Data 2.5.2) were computed for each ramp meter as the ratio of "proper on/off state" time to total time (sum of ramp meter "proper on/off state" plus ramp meter "not proper on/off state" time). An “on” entry in any on/off column was interpreted to mean that the associated equipment was in the proper on/off state for the entire duration since the last check. An "x" mark in any on/off column was interpreted to mean that the associated equipment was not in the proper on/off state for the entire duration since the last check.

Percent proper vehicle presence response (Data 2.6.1) was computed for each ramp meter as the ratio of proper response time to total response time (sum of "proper response" time plus "not proper response" time). A “check” (√) mark in a Vehicle Present or Absent Treatment Column was interpreted to mean that the ramp meter response was proper for the entire duration since the last check. An "x" mark in a Vehicle Present or Absent Treatment Column meant that the ramp meter response was not proper for the entire duration since the last check.

4.6.2.10 Results from Data Gathered in Support of Performance Measure 2.5

Percent Signal Correctly Powered On/Off (Data 2.5.1) – The data sheets in Appendix H show that at Grand Avenue, the ramp signal was powered on correctly 100 percent of the time during scheduled ramp-metering periods. At other times, the signals were off. At Tustin Ranch Road, the ramp signal was also correctly on 100 percent of the time during scheduled ramp-metering periods and off at other times. At Jamboree Road, the ramp signal turned off one hour into an afternoon run on March 3, 1998 when the ramp meter generator tried to start and couldn’t. The radio receiver in the ramp trailer was not able to receive the commands from the surveillance trailer during the generator starting sequence. Based on the evaluation criteria, the Jamboree Road ramp trailer was correctly on and off for 25 of the 29 checks or 86 percent of the time it was monitored as part of the test.

Percent Meter-on Sign Correctly Powered On/Off (Data 2.5.2) – At Grand Avenue, the meter-on sign operated correctly 100 percent of the time. There was no permanent meter-on sign at Tustin Ranch Road. Therefore the portable meter-on sign was not installed either. The portable meter-on sign was not working at Jamboree Road because the radio transmitter/receiver combination between the ramp trailer and the sign did not have the transmission capabilities needed for the task. After the FOT was complete, new radios were installed, but their operation was not verified by the evaluator.

4.6.2.11 Results from Data Gathered in Support of Performance Measure 2.6

Percent Proper Vehicle Presence Response (Data 2.6.1) – Once the command synchronization problem between the surveillance and ramp meter trailers was fixed, the ramp signals generally followed the demand of the vehicles on the ramp. Exceptions were noted and linked to the color of the vehicles during the day and the relative location of headlight beams and the VIP detection zones at night. More data are required to fully quantify this phenomenon. When vehicles were missed and the ramp had two lanes or the camera field of view allowed VIP detection zones to be placed several car lengths upstream of the stop bar, the VIP generally detected another vehicle and changed the signal to green, allowing both to pass. Based on the evaluation criteria, the Grand Avenue ramp trailer correctly treated the presence of vehicles 44 out of 55 times or 80 percent of the time it was monitored as part of the test. The Tustin Ranch Road ramp trailer correctly treated the presence of vehicles 29 out of 37 times or 78 percent of the time it was monitored. The Jamboree Road ramp trailer correctly treated the presence of vehicles 25 out of 26 times or 96 percent of the time it was monitored.

4.6.2.12 Data Collection Procedures for Performance Measure 2.7

Data 2.7.1 supports Performance Measure 2.7, Ramp meter problems.

Data 2.7.1: Identity of ramp meter problems

Part II of each Ramp Meter Operability Data Sheet contained 20 numbered lines. When the first "x" mark, denoted by “x1”, was placed on Part I of a data sheet, a note was entered on Part II of the data sheet to explain the nature of the problem associated with “x1”. When the second "x" mark, denoted by “x2” (reading from left to right and top to bottom), was placed on Part I of the data sheet, an explanation was likewise entered on Part II of the data sheet. The process continued with an explanation provided for each "x" mark. Another source of information about ramp meter issues related to VIP detection zones was the notes taken by the evaluator. These sources of information provided Data 2.7.1, identity of ramp meter problems.

4.6.2.13 Results from Data Gathered in Support of Performance Measure 2.7

The comments and problems noted on the Ramp Meter Operability Data Sheets included:

- Daytime vehicle detection on ramps was sometimes affected by the relative color of the vehicle with respect to the road surface;
- Nighttime vehicle detection on ramps was affected by alignment of VIP detection zones and vehicle headlight beams;
- At Grand Avenue, the signals followed the 170 controller commands after the delay on the digital input board was changed to 100 milliseconds from 5 seconds. However, the VIP detectors continued to miss vehicles from time to time;
- Ramp overflow detection by VIPs will most likely require an additional camera to detect vehicles at the ramp entrance;
- The ramp trailer generator at Jamboree Road could not start on demand, causing the ramp signal to turn off;
- Faulty optical isolators caused dim signals and bleed-through to light a signal that should not be lighted;
- The need for a better radio link between ramp meter trailers and meter-on signs was verified.

A summary of the data recorded in the evaluator’s notes appears in Table 4-8.

Table 4-8. Issues concerning VIP detection zones used for ramp signal control

Site	Date	Issue
Grand Avenue and Tustin Ranch Road	Jan. 28, 1998 a.m.	Missing some vehicle detections on the ramp; more dark vehicles missed than lighter colored ones. Causes longer queues. At Grand Avenue, missing about 1-2 cars every 1/2 hour. Missing more cars at Tustin Ranch Road; increased metering rate to 12 veh/min from 10 to help reduce queue at Tustin Ranch.

Tustin Ranch Road	Jan. 28, 1998 a.m.	No luminaries. Therefore, ramp is very dark before dawn. Auto headlights trigger the VIP demand detector long before the vehicle arrives at the detector. Thus, there is no delay for vehicles on the ramp as the signal has already turned green.
Jamboree Road	Feb. 5, 1998	Because the surveillance trailer is close to the ramp, the VIP camera's field of view does not include a count zone for the number of vehicles entering the mainline. As at the other sites, it cannot create a queue overflow detector either. Another limitation at Jamboree Road is that the demand zone cannot be extended upstream from the signal to detect vehicles that may stop more than one car length from the signal. However, even with these limitations, the mobile ramp signal appears to function adequately at this site.
Tustin Ranch Road	March 4, 1998 p.m.	Cargo container truck at stop bar did not get a green signal. Neither the aluminum-colored truck body not its headlights triggered the demand detector.
Tustin Ranch Road	March 5, 1998 7 a.m.	Leading dark-colored auto followed by white auto were not detected by demand detector. Signal remained red and was manually changed to green ball six minutes later to relieve the queue. Used supervisory computer to add more demand detectors upstream of the stop bar. The supervisory computer showed that the existing detectors were directional, whereas the detectors at the other sites were not. Changed the detectors to non-directional (requires suspending shadow processing by AutoScope) and added two additional demand detectors upstream of the original ones. The two added detectors were in the shape of an X. The total number of demand detectors in the right ramp lane was now five. All were connected with OR logic. The five detectors filled the entire field of view of the camera.
Grand Avenue	March 5, 1998 a.m.	Vehicles appear to be waiting longer than 2 seconds for a green ball. In addition, green does not change to red immediately. Called software subcontractor to investigate the problem; changed delay on digital input board to 100 msec. Also missing calls, e.g., a black vehicle in the left ramp lane did not get a green ball after 6-8 seconds.

4.6.3 Test Objective 3 - Freeway Deployment Institutional Issues

The evaluation of freeway deployment institutional issues had as its objective the identification of the advantages, disadvantages, and costs related to using the surveillance and ramp meter trailers for traffic management operations and research.

4.6.3.1 Measures of Performance

The measures of performance for this assessment are:

- Measure 3.1: Advantages of freeway deployment
- Measure 3.2: Disadvantages of freeway deployment
- Measure 3.3: Costs of freeway deployment.

4.6.3.2 Test Data

The data collected in support of each performance measure are:

Measure 3.1: Advantages of freeway deployment

Data 3.1.1: Identity of advantages of freeway deployment

Measure 3.2: Disadvantages of freeway deployment

Data 3.2.1: Identity of disadvantages of freeway deployment

Measure 3.3: Costs of freeway deployment

Data 3.3.1: Identity of cost items related to freeway deployment.

4.6.3.3 Data Collection Procedure and Results

The data collected in support of Objective 3 are described below.

Data 3.1.1: Identity of advantages of freeway deployment

Institutional issues that concerned freeway deployment were discussed for many months prior to the test and led to a preliminary list of freeway deployment advantages:

- Advantage F1: Allows remote surveillance of freeway mainline
- Advantage F2: Allows remote surveillance of freeway onramps
- Advantage F3: Facilitates coordination between Caltrans Operations and Caltrans Maintenance Divisions.

The evaluator requested written statements from the lead Caltrans personnel involved with the I-5 Test confirming the identity the advantages of deploying the trailers in a freeway setting for traffic management operations and research. The result of this activity was Data 3.1.1, the identity of the advantages of freeway deployment.

Data 3.2.1: Identity of disadvantages of freeway deployment

As a result of the institutional issue discussions, the freeway deployment disadvantages were identified as:

- Disadvantage F1: Requires complex intra-agency coordination
- Disadvantage F2: Represents potential roadway hazard
- Disadvantage F3: Requires state to acquire new expertise
- Disadvantage F4: Requires special security arrangements.

The evaluator requested written statements from the lead Caltrans personnel confirming the identities of the disadvantages. The result of this activity was Data 3.2.1, the identity of the disadvantages of resource sharing.

Data 3.3.1: Identity of cost items related to freeway deployment

As a result of the institutional issue discussions, the initial list of cost items related to freeway deployment was identified as:

- Cost Item F1: Trailer movement and storage
- Cost Item F2: Trailer fuel and maintenance
- Cost Item F3: TMC equipment installation
- Cost Item F4: Training of Caltrans personnel.

The evaluator requested written statements from the lead Caltrans personnel confirming that this list correctly identified the cost items. The costs to date and those anticipated for future trailer use were also requested. The result of this activity was Data 3.3.1, the identity of the cost items related to freeway deployment.

LPG Fuel Consumption (Cost Item F2) – The cost of liquid propane fuel for the generators in the surveillance trailers was estimated from the generator-use logs kept in the surveillance trailers. The logs (included in Appendix I) indicated when the liquid propane gas (LPG) tanks were refilled and noted the generator in-use hours at which this event occurred. Unfortunately, the entries do not allow an accurate assessment of the fuel use per hour of generator ontime to be made as may be seen from the scatter in Table 4-9. The capacity of the tank in the surveillance trailer is 88 gallons of liquid. (The capacity of the tank in the ramp meter trailer is 60 gallons of liquid.) LPG fuel cost was approximately $1.75/gallon. Assuming the most likely estimates of LPG consumption are represented by the values under 0.01136 tank/hr (1 gallon/hr), the average LPG used by a surveillance trailer is approximately 0.00522 tank/hr or 0.460 gallon/hr. Under this assumption, the estimated cost of LPG is $0.80/hr for surveillance trailer operation. If all the data in Table 4-9 are averaged, the LPG use is 0.01116 tank/hr (0.982 gallon/hr) or $1.72/hr.

Table 4-9. LPG fuel consumption by the surveillance trailers

Site	Date	Hours	Delta Hours	Fuel Level	Delta Fuel	Approximate Fuel Volume/Operating Hour
Main Place	11/10/97	1058.6		1/2		
Surveillance Trailer	12/4/97	1110.2	51.6	3/4	1/4	0.00484 tank/hr=0.426g/hr
Grand Avenue	10/8/97	552.6		3/4		
Surveillance Trailer	11/20/97	671.9	119.3	7/16 (?)	5/16	0.00262 tank/hr=0.231g/hr
	12/2/97	699.3		1/4		
	12/4/97	705.1	5.8	3/4	1/2	0.08621 tank/hr=7.586g/hr
	3/16/98	1322.7		3/4		
	5/5/98	1600.3	277.6	0	3/4	0.00270 tank/hr=0.238g/hr
First Street	9/16/97	1124.2		1/2		
Surveillance Trailer	10/7/97	1159.7	35.5	3/4	1/4	0.00714 tank/hr=0.629g/hr
	11/4/97	1210.8	51.1	1/2	1/4	0.00489 tank/hr=0.431g/hr
	1/8/98	1306.1		7/16 (?)		
	1/19/98	1329.8	23.7	3/4	5/16	0.01319 tank/hr=1.160g/hr
	1/23/98	1415.6		3/4		
	2/11/98	1572.9	157.3	1/4	1/2	0.00318 tank/hr=0.280g/hr
Tustin Ranch Road	1/19/98	1063.5		5/8		
Surveillance Trailer	1/22/98	1125.6	62.1	0	5/8	0.01006 tank/hr=0.885g/hr
Jamboree Road	3/25/98	1409.2	126.4	3/4		
Surveillance Trailer	4/9/98	1449.1	39.9	1/2	1/4	0.00627 tank/hr=0.551g/hr
Culver Drive	6/19/97	718.0		3/4		
Surveillance Trailer	6/24/97	740.4	22.4	5/8	1/8	0.00558 tank/hr=0.491g/hr
	6/26/97	760.7	20.3	3/4	1/8	0.00616 tank/hr=0.541g/hr
	7/8/97	790.5	29.8	5/8	1/8	0.00419 tank/hr=0.369g/hr
	7/10/97	811.3	20.8	3/4	1/8	0.00601 tank/hr=0.529g/hr
	7/15/97	869.4	58.1	1/2	1/4	0.00430 tank/hr=0.379g/hr

4.6.3.4 Other Lessons Learned from Test Objective 3

Summaries of other lessons learned from interviews conducted in support of Test Objective 3 are:

GUI Trailer Location Updates - Whenever a trailer is moved to a new freeway location, the field device database on the TMC GUI must be updated to reflect the new trailer location. If not, the trailer icon on the TMC map display will not reflect the actual trailer location, and will potentially confuse personnel as to the true location of the trailer. 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 later. 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 trailer locations.

GUI Trailer Cluster Icons - The trailer location icon cluster on the TMC 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.

Construction Zones - Construction at the Katella Avenue interchange of I-5 began in the Spring of 1998. Freeway widening and the Disneyland expansion are expected to have a negative impact on traffic flow through Spring of 1999. Both the District 12 and Anaheim TMCs have identified this location as a high priority site for temporary surveillance. Placing a surveillance trailer in this area has been frustrated by lack of commercial power and frequent changes to the configuration of the construction site. As of August 1998, the Caltrans contractors had been unable to accommodate a surveillance trailer at the Katella Avenue interchange. It has been suggested that construction zone dust and vibrations may compromise trailer operations during excavation activities, but these concerns have not been substantiated.

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. The contractor would have to determine the cost to protect the trailer and include such costs in his bid. For example, the contractor could place K-rail around the trailer to protect it from being hit by vehicles. The contractor would also have to remove graffiti from the *K*-rail within 48 hours.

Ramp Meter Trailers - There has been no experience to date using the ramp meter trailers in construction zones. One Caltrans resident engineer explained that Caltrans doesn’t want ramp metering in construction zones because they cannot maintain the system and it will not help the mainline (which normally is congested in construction zones anyway). There appears to be no current interest in using the ramp meter trailers for a temporary ramp meter installation. One Caltrans ramp meter engineer explained that Caltrans would prefer a permanent ramp meter installation to a temporary installation in order to ensure driver acceptance and compliance. Anaheim is open to the idea of using the ramp meter trailers for special event traffic management. It has been suggested that the ramp meter trailers be used to meter parking lot egress.

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 engineers need to identify the controlling bottleneck. This requires a thorough analysis of traffic count 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 count data that would otherwise be unavailable, thereby supporting the development of ramp meter plans.

4.6.4 Test Objective 4 - Information Sharing Institutional Issues

The objective of evaluating institutional issues associated with information sharing was to identify the advantages, disadvantages, and cost items related to Caltrans sharing freeway traffic video and data with the Anaheim TMC and the UCI-ITS Laboratory over the wireless communications network.

4.6.4.1 Measures of Performance

The measures of performance for this assessment are:

- Measure 4.1: Advantages of sharing freeway video and data
- Measure 4.2: Disadvantages of sharing freeway video and data
- Measure 4.3: Costs of sharing freeway video and data.

4.6.4.2 Test Data

The data collected in support of each performance measure are:

Measure 4.1: Advantages of freeway video and data sharing

Data 4.1.1: Identity of advantages of sharing freeway video and data

Measure 4.2: Disadvantages of freeway video and data sharing

Data 4.2.1: Identity of disadvantages of sharing freeway video and data

Measure 4.3: Costs of freeway video and data sharing

Data 4.3.1: Identity of cost items related to sharing freeway video and data

4.6.4.3 Data Collection Procedure and Results

The data collected in support of Objective 4 are described below.

Data 4.1.1: Identity of advantages of sharing freeway video and data

Institutional issues concerning the sharing of freeway video and data were discussed for many months prior to the test, resulting in a preliminary list of advantages. These are:

- Advantage D1: Allows the Anaheim TMC to better manage city operations in the vicinity of I-5
- Advantage D2: Allows the UCI-ITS Laboratory to readily incorporate real-time freeway data into ongoing transportation research
- Advantage D3: Facilitates inter-agency cooperation between Caltrans District 12, Anaheim TMC, and UCI-ITS Laboratory.

The evaluator requested written statements from Caltrans, Anaheim, and UCI personnel involved with the I-5 Test confirming this list correctly identified the advantages of sharing freeway video and data among Caltrans, Anaheim, and the UCI-ITS Laboratory. The result of this activity was Data 4.1.1, the identity of the advantages of sharing freeway video and data.

Data 4.2.1: Identity of disadvantages of freeway video and data sharing

As a result of the institutional issue discussions, the disadvantages of sharing freeway video and data were identified as:

- Disadvantage D1: Requires operators at different facilities to share common video controls
- Disadvantage D2: Requires Anaheim TMC operators and UCI-ITS personnel to acquire new expertise
- Disadvantage D3: Requires Anaheim and UCI to purchase a supervisory computer or other software to display the VIP data.

The evaluator requested written statements from Caltrans, Anaheim, and UCI personnel confirming this list correctly identified the disadvantages of sharing freeway video and data among the three organizations. The result of this activity was Data 4.2.1, the identity of the disadvantages of sharing freeway video and data.

Data 4.3.1: Identity of cost items related to sharing freeway video and data

As a result of the institutional issue discussions, cost items related to sharing freeway video and data were assembled as:

- Cost Item D2: Anaheim TMC and UCI-ITS Laboratory equipment installation
- Cost Item D1: Public utilities and maintenance costs.

The evaluator requested written statements from Caltrans, Anaheim, and UCI personnel to confirm the list identified the cost items associated with sharing freeway video and data among Caltrans, Anaheim, and the UCI-ITS Laboratory. Data quantifying the costs expended to date and those anticipated for future trailer use were also requested. The result of this activity was Data 4.3.1, the identity of the cost items related to the sharing of freeway video and data.

4.6.4.4 Other Lessons Learned from Test Objective 4

Summaries of other lessons learned from interviews conducted in support of Test Objective 4 are:

Video Sharing - Shared control of a surveillance camera by allied agencies working from different sites is customary. 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. For example, if another agency has better control of a given camera, the District 12 TMC will let the other agency control it. If the District 12 TMC wants a different view, they call the other agency and ask the camera to be moved.

Research - Researchers at the UCI-ITS laboratory are also interested in using the surveillance trailers to fill gaps in the available inductive loop database. To date, none of the UCI-ITS researchers have 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 to some researchers) are not available.

4.7 Pilot Tests

Two pilot tests were planned in conjunction with the I-5 Test, the Pilot Video Image Processor Performance Assessment and the Pilot Spread Spectrum Radio Performance Assessment. The Video Image Processor Assessment was designed to measure the relative accuracy of the VIP with respect to the ILD in detecting individual vehicles. A form of this test was conducted when the laptop computers were used to poll and record the data from the 170 controllers. The differences between this and the pilot test were that 30-second vehicle counts are output by the 170 instead of individual vehicle counts, and simultaneous video of the traffic flow was not recorded as “ground truth” data. The Spread Spectrum Radio Assessment was designed to measure how many information packets were dropped during transmission from the surveillance trailer to the District 12 TMC. Both required the data logger. Repeated attempts were made by Caltrans to have their contractors, first Hughes and then Iron Mountain Systems, complete the design and programming of the data loggers. However, these tasks could not be completed in the time allotted for the FOT. The pilot test procedures are described in the Evaluation Plan.

4.8 Quantitative Data Acquisition and Analysis Procedures for Performance Measure 2.4 (VIP Data Believability)

The inability of the District 12 ATMS to access the VIP data in the surveillance trailers led to the dual laptop computers being used in the field to record the inductive loop and VIP volume and occupancy data. Since the primary purpose of the FOT was to evaluate the ability of the mobile trailers to support ramp metering, the speed data calculated by the 170 controllers in the field were not analyzed. Doing so would have increased the complexity of the analysis, as special software would have to be written. The comparison of the ILD- and VIP-produced speeds would have been performed had the ATMS software been able to access the 170 controller connected to the VIP. Instead, the procedures below were developed to gather data to support Performance Measure 2.4, VIP data believability.

Two to three days of data were collected at each of the three ramp meter trailer locations, as shown in Table 4-10. No rain or incidents occurred at the evaluation sites during these data collection periods.

The recording of data by the laptop computers is illustrated in Figure 4-21. The laptop that polled the 170 controller connected to the VIP was placed in the trailer. The other laptop was located in the roadside cabinet that housed the 170 controller that processed the ILD data. The laptops simulated the polling and data capture features of the ATMS computer system at District 12, which was not available during the FOT.

Table 4-10. Ramp meter data collection times

Site	AM Data Collection Date and Time Interval		PM Data Collection Date and Time Interval
Tustin Ranch	March 5, 1998	6:15-9:30	––

Road	March 9, 1998	6:15-9:30	March 9, 1998	14:15-19:00
	March 10, 1998	6:15-9:45	March 10, 1998	16:15-19:00
Grand Avenue	April 14, 1998	6:15-9:30	April 14, 1998	14:45-19:00
	April 16, 1998	6:15-9:30	April 16, 1998	16:30-19:00
Jamboree Road	—		March 11, 1998	15:15-19:00
	March 12, 1998	6:15-9:30	March 12, 1998	15:15-19:00
	March 13, 1998	6:15-9:45	March 13, 1998	15:15-19:00

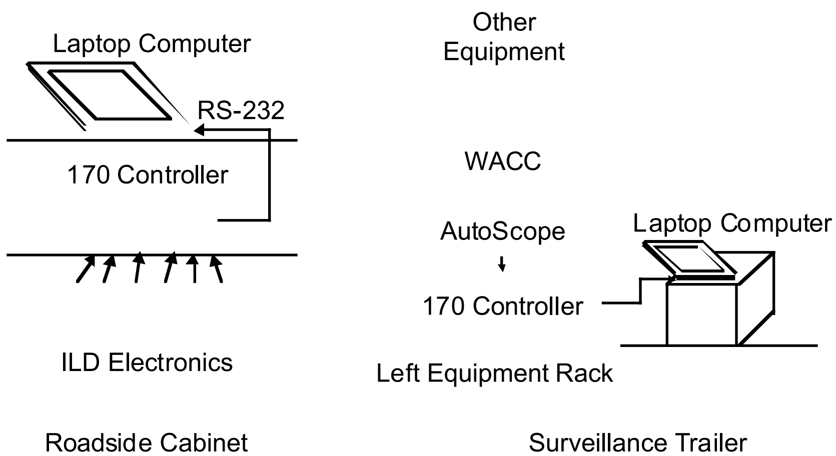


Figure 4-21. ILD and VIP data recording from 170 controllers using laptop computers

The clocks in both laptops were synchronized to within one 30-second polling interval. The clock in the 170 controller in the surveillance trailer drifted several minutes during a 4-hour run because of the non-ideal frequency stabilization that was characteristic of the portable electric power generation system. The laptop computer sent a synchronization signal to the 170 every hour in order to compensate for 170-clock drift.

4.8.1 Mainline Occupancy and Volume

ILD data were recorded from the inductive loops already installed in the mainline lanes. VIP data were obtained from the AutoScope 2004 VIP (part of the equipment in the surveillance trailer) using the loop emulation output. One of the black and white Burle cameras that supplied imagery to the AutoScope VIP was pointed at the mainline, and the other was pointed at the onramp to view the ramp signal area.
The data from all test runs are reported chronologically in a similar manner, namely (1) a series of plots of lane-by-lane occupancy and volume data versus time, (2) combined occupancy and volume data over all lanes reporting good data with respect to time,

(3) averages of occupancy and volume data for all lanes reporting good data, and (4) percent differences in average occupancy and total volume between the VIP and ILD measurements. Good data are ILD and VIP data that are not reported by the 170 controllers (that process the data) as suspect or affected by a detector malfunction. The first series of plots showing the lane-by-lane time series data are presented for most tests, even if only one of the ILD or the VIP data sets is good. However, the information in the second through fourth data presentations is only shown for lanes where both good ILD and VIP data were recorded. Data are omitted from further analysis at time intervals when one detector reports good data, but the second detector reports suspect data or a detector malfunction. This is done to eliminate biases from the average occupancy and volume values that are reported. ILD and VIP data were collected over the first five lanes of the mainline, with the lane closest to the shoulder designated Lane 5. Data were not collected in the high occupancy vehicle lanes that were located to the left of the leftmost general vehicle lane (designated Lane 1).

Thirty-second data (polled from the 170 controller) integrated over a 15-minute interval are plotted in the figures in the first and second data presentations. The 15-minute averaged data were used for analysis because the data file that was output by the data-polling program could not directly write the data to an electronic computer file. Therefore, the data had to be printed and then manually re-entered into a spread sheet program. Thus, using 15-minute data made the manual re-entry task manageable for the multi-hour evaluation runs.

After the data from the individual runs are described, the overall averages of the percent differences in lane occupancies and volumes over the 14 data runs are presented. These averages describe the expected performance of the trailer system in measuring traffic volume for the ramp-metering application.

4.8.2 Ramp Signal Demand and Metering Rate

In addition to the mainline occupancies and volumes, the laptop computers also recorded ILD and VIP data from the demand, passage, on, and queue detectors on the I-5 Freeway onramps. ILD data were recorded from the inductive loops already installed on the ramps. VIP data were obtained from the AutoScope using imagery from the Burle camera that was pointed at the onramp. Only the ILD queue detectors were monitored. Their location at the entrance to the ramp made it impossible for the Burle camera to view this area, since the camera was pointed near the ramp signal (that was closer to the ramp exit onto the mainline than to the ramp entrance). Hence, a VIP ramp queue detector could not be implemented. The analyzed data from the ILD and VIP detectors included metering rate used, local responsive rate, time-of-day rate, and ramp demand occupancy and volume. At the Tustin Ranch Road and Jamboree Road sites, long queues formed when traffic backed up to the start of the onramps. In order to try to minimize the queue length, the metering rate on the VIP 170 controller was set to the maximum value permitted in the time-of-day tables. The time-of-day rate in the ILD 170 controller was not adjusted since we did not want to disturb the permanent metering rate of the ramp. Therefore, the time-of-day meter rate plots and the meter rate used plots in Figures D-108 through D-135 show different values for the ILD and VIP detectors. A long queue was not a consideration at the Grand Avenue site and, consequently, the ILD and VIP time-of-day rates were the same at this venue.

The local responsive ramp-metering algorithm that resides in the 170 controllers at the onramps works as follows. First, a time-of-day (TOD) rate is programmed into the 170 controller. This rate may be either (1) entered manually by a traffic engineer into the 170 controller in the field, (2) sent by a TMC operator to the 170 in the field, or (3) sent by area engineers from their office to the 170 in the field. Second, a critical value for the average 3-minute mainline volume/lane (currently 75 vehicles) and a critical value for the average 1-minute mainline occupancy/lane (currently 20 percent) are entered into the 170 controller. Third, a local responsive (LR) rate based on mainline volume or mainline occupancy is calculated. The LR rate based on mainline volume is given by

$$\text{LR Rate}_V = \frac{\text{Mainline total volume}}{\text{Number of lanes}} - \text{Critical volume.} \tag{4-1}$$

The LR rate based on mainline occupancy is given by

$$\text{LR Rate}_O = \text{Average occupancy} - \text{Critical occupancy.} \tag{4-2}$$

Fourth, if either the locally measured mainline volume or occupancy is less than the critical value, then the local responsive meter rate is used, provided the LR rate is greater than the value in the TOD table. If the TOD rate is larger, then it is used. If the locally measured mainline volume or occupancy is greater than the critical value, then the TOD rate is also used.

The total mainline volume listed on the ramp demand and metering rate reports does not represent the same total mainline volume parameter listed on the mainline occupancy and volume reports. The mainline volume shown on the ramp data report is the value output by the 170 controller before adjustment for suspect data or malfunctioning detectors. The value on the mainline data report is the adjusted value. The adjusted value is found as follows. Suppose that the mainline consists of 5 general purpose vehicle lanes and that the Lane 5 detectors are not operational, but the Lane 1 through Lane 4 detectors are working properly. The adjusted total mainline volume is calculated by summing the volumes from Lanes 1 through 4 and multiplying the result by 5/4. The local responsive ramp-metering algorithm uses the adjusted mainline total volume.

Section 4.9 describes the results of the mainline occupancy and volume data analysis. Section 4.10 describes the results of the ramp signal demand and metering rate analysis.

4.9 Mainline Occupancy and Volume Data Analysis

The following sections describe the rush hour interval occupancy and volume results obtained at each morning and afternoon evaluation run at which 170-controller polling data were recorded on the laptop computers.

4.9.1 Tustin Ranch Road AM Rush Hour Occupancy and Volume Data for 3/5/98

Comparisons of the March 5, 1998 lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 4 of the I-5 mainline at the Tustin Ranch Road site are displayed in Figures J-1 to J-4, respectively, of Appendix J. The data are plotted as a function of time for the 6:15 to 9:30 morning rush hours.

The 170 computers that processed the ILD and VIP detector inputs reported a malfunction during the acquisition or processing of all of the ILD data and most of the VIP data from Lane 5, the lane closest to the right shoulder, as shown in Tables J-1 and J-2 of Appendix J. Hence, Lane 5 data are not plotted for the Tustin Ranch Road site. Figure J-1 does not contain ILD data as the 170 controller reported suspect data or detector malfunctioning for Lane 1 during the recording interval. Figures J-2 through J-4 show that the Lane 2 through Lane 4 lane occupancies and volumes from the ILDs and VIP generally track one another over time.

Figure J-5 compares the average occupancy and total volume measured by the ILDs and VIP on mainline Lanes 2 to 4 as a function of time. The two sets of ILD and VIP values track one another well. Figure J-6 displays the averages of the lane occupancy and total volume reported by the ILDs and VIP during the morning rush hour interval. Data are shown for each lane and for Lanes 2 to 4 combined (the lanes reporting good data for both the ILDs and VIP). Figure J-7 shows the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 2 to 4 combined. The ILD value is used as the reference for the percent difference calculation. The VIP occupancies have a smaller percent difference with respect to the ILD occupancies, than do the VIP lane volumes compared with the ILD lane volumes.

Two effects contribute to the less than optimal performance of the VIP compared with the inductive loops, especially in lanes further from the trailer location. Both effects are caused by the relatively low operational height of the VIP cameras above the road surface [approximately 32 feet (9.8 meters)] as constrained by the height of the fully extended mast on the surveillance trailer. Tall vehicles, such as large commercial trucks, that project their image into adjacent lanes produce the first effect. The VIP detector zones in the adjacent lanes detect the truck as if it was actually traveling in those lanes. Depending on the location of the surveillance trailer with respect to the roadway, the tall vehicle can project its image into 1, 2, or 3 adjacent lanes. Thus, the VIP will overcount vehicles if this effect is present. The second factor that degrades VIP performance is blockage of shorter vehicles, such as passenger cars, in the lanes further from the camera by taller vehicles traveling in the lanes closer to the camera. This effect appears to be less prevalent than the detection of a tall vehicle in more than one lane.

Because of these two effects, it was anticipated that the vehicle counts and lane occupancies calculated by the VIP would be closest to the values calculated from the inductive loops in the lane nearest the surveillance trailer containing the camera used with the VIP, i.e., the rightmost lane. In this lane, there would be no false images of tall vehicles or blockage of short vehicles by the taller ones. This premise is somewhat substantiated by the data in Figure J-7. Data in other runs and at other sites support this premise to a greater degree. The smallest percent differences of VIP data with respect to ILD data occur in Lanes 2 and 4. For Lane 4, the percent difference is –37.4 for the total volume (indicating significant overcounting by the VIP) and -3.8 for the occupancy averaged over the morning rush-hour period. For Lane 2, the percent difference is –37.3 for the total volume (significant overcounting by the VIP) and –6.0 for the occupancy. Lane 3 (the middle freeway lane) displayed the greatest percent differences, apparently from the domination of vehicle image projection into this lane. Here the percent differences were –61.7 for the volume and –28.0 for the occupancy. Over the combination of Lanes 2 through 4, the percent differences were –44.4 for volume and –10.8 for occupancy.

4.9.2 Tustin Ranch Road AM Rush Hour Occupancy and Volume Data for 3/9/98

Figures J-8 to J-11 compare the March 9, 1998 lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 4 of the I-5 mainline at the Tustin Ranch Road site. The data are plotted as a function of time for the 6:15 to 9:30 morning rush hours.

The 170 computers that processed the ILD and VIP detector inputs reported a malfunction during the acquisition or processing of all of the ILD data and most of the VIP data from Lane 5 as shown in Tables J-3 and J-4. Hence, Lane 5 data are not plotted. Figure J-8 does not contain ILD data as the 170 controller reported suspect data or detector malfunctioning for Lane 1 during the recording interval. Figures J-9 through J-11 show that the Lane 2 through Lane 4 lane occupancies and volumes from the ILDs and VIP generally track one another over time.

Figure J-12 compares the average occupancy and total volume measured by the ILDs and VIP on mainline Lanes 2 to 4 as a function of time. The two sets of ILD and VIP values track one another well. Figure J-13 displays the averages of the lane occupancy and total volume reported by the ILDs and VIP during the morning rush hour interval. Data are shown for each lane and for Lanes 2 to 4 combined (the lanes reporting good data for both the ILDs and VIP). Figure J-14 displays the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 2 to 4 combined. The VIP occupancies have a smaller percent difference with respect to the ILD occupancies, than do the VIP lane volumes compared with the ILD lane volumes. In Lane 4, the percent difference of the VIP data with respect to the ILD data is -2.1 for the total volume (slight overcounting by the VIP) and -43.5 for the occupancy averaged over the morning rush-hour period. It appeared that Lane 3 (the middle freeway lane) displayed the greatest percent differences, apparently from the domination of vehicle image projection into this lane. The Lane 2 percent differences are again similar to those of Lane 4. Over the combination of Lanes 2 through 4, the -50 percent difference in volume indicated significant overcounting by the VIP. The –10.3 percent difference in occupancy was in the small range.

4.9.3 Tustin Ranch Road PM Rush Hour Occupancy and Volume Data for 3/9/98

Figures J-15 to J-18 display the March 9, 1988 afternoon rush hour lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 4 of the I-5 mainline at the Tustin Ranch Road site. These data were acquired from 14:15 to 19:00 hours. In this test, the 170 computer that processed the ILD detector inputs reported a malfunction during the acquisition or processing of data from Lane 5 as shown in Tables J-5 and J-6. Similar error reports were obtained for most of the VIP data from Lane 5. Hence, Lane 5 data are not plotted for this run either. Figures J-15 through J-18 do not contain ILD or VIP data between 14:15 to 15:45 hours because the VIP data were suspect or the detector was reported as malfunctioning during these times. The plot of Lane 1 data begins at 17:45 hours, as this is when both good ILD and VIP data were recorded. Generally, the lane occupancy and volumes from the ILDs and VIP track one another over time.

Figure J-19 compares the average occupancy and total volume measured by the ILDs and VIP on mainline Lanes 2 to 4 as a function of time. The two sets of ILD and VIP values track one another well. Figure J-20 displays the averages of the lane occupancy and total volume reported by the ILDs and VIP. Data are shown for each lane and for Lanes 1 to 4 combined and Lanes 2 to 4 combined. Figure J-21 shows the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 1 to 4 combined and Lanes 2 to 4 combined. In this data set, the percent differences between the VIP and ILD occupancies and volumes are of the same order of magnitude. The percent differences for Lane 4 (the lane closest to the surveillance trailer and camera) are smallest. The percent difference of the VIP data with respect to the ILD data is -48.5 for the total volume (significant overcounting by the VIP) and -52.8 for the occupancy in Lane 4 averaged over the afternoon rush-hour period. Lane 1 (the leftmost freeway lane designated for general traffic) displayed the greatest percent differences, apparently from having the most vehicle image projection into this lane.[6]

4.9.4 Tustin Ranch Road AM Rush Hour Occupancy and Volume Data for 3/10/98

Figures J-22 to J-25 compare the March 10, 1998 lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 4 of the I-5 mainline at the Tustin Ranch Road site for the morning rush from 6:15 to 9:45 hours. The 170 computers that processed the ILD and VIP detector inputs reported malfunctions during the acquisition or processing of data from Lane 5 as shown in Tables J-7 and J-8. Hence, Lane 5 data are not plotted for the Tustin Ranch Road site. Figure J-22 does not contain ILD data as the 170 controller reported suspect data or detector malfunctioning for Lane 1 during the recording interval. Figures J-23 through J-25 show that the lane occupancy and volumes from the ILDs and VIP generally track one another over time.

Figure J-26 compares the average occupancy and total volume measured by the ILDs and VIP on mainline Lanes 2 to 4 as a function of time. Again, the two sets of ILD and VIP values track one another well. Figure J-27 contains the averages of the lane occupancy and total volume reported by the ILDs and VIP. Data are displayed for each lane and for

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6. Lane 1 ILD data were not available for the morning rush hour run on this day. Thus, Lane 3 data were reported to have the largest percent difference for the morning run.

Lanes 2 to 4 combined (the lanes reporting good data for both the ILDs and VIP). Figure J-28 shows the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 2 to 4 combined. As in the March 9 data set, the VIP occupancies have a smaller percent difference with respect to the ILD occupancies, than do the VIP lane volumes compared with the ILD lane volumes.

The percent differences in occupancy and volume measurements for Lane 4 (the lane closest to the surveillance trailer and camera) are smallest, although there is significant overcounting by the VIP, even in Lane 4. Lane 5 comparisons are not available because of ILD malfunctioning in this lane. The percent difference of the Lane 4 VIP data with respect to the ILD data is -35.2 for total volume and -3.9 for occupancy averaged over the morning rush-hour period. Lane 3 (the middle freeway lane) again displayed the greatest percent differences during the morning run, apparently caused by vehicle image projection.

4.9.5 Tustin Ranch Road PM Rush Hour Occupancy and Volume Data for 3/10/98

Figures J-29 to J-32 display the March 10, 1998 afternoon rush hour lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 4 of the I-5 mainline at the Tustin Ranch Road site. These data were acquired from 16:15 to 19:00 hours. In this run, the 170 computer that processed the ILD detector inputs reported a malfunction during the acquisition or processing of data from Lane 5 as shown in Tables J-9 and J-10. Similar error reports were obtained for most of the VIP data from Lane 5. Hence, Lane 5 data are not plotted for this run either. As in the other runs, lane occupancies and volumes from the ILDs and VIP track one another over time.

Figure J-33 compares the average occupancy and total volume measured by the ILDs and VIP on mainline Lanes 2 to 4 as a function of time. The two sets of ILD and VIP values track one another well. Although some ILD data were obtained from Lane 1, the accuracy of these values and the corresponding VIP values are questionable as shown later by the large percent differences recorded in Figure J-35. Figure J-34 displays the averages of the lane occupancy and total volume reported by the ILDs and VIP. Data are shown for each lane and for Lanes 2 to 4 combined (the lanes reporting good data for both the ILDs and VIP). Only VIP data are available for Lane 5 as noted earlier.

Figure J-35 shows the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 2 to 4 combined. The percent differences between the VIP and ILD occupancies and volumes are of the same order of magnitude as in the afternoon run of March 9. Again, the percent differences for Lane 4 (the lane closest to the surveillance trailer and camera) are smallest, although there is significant overcounting by the VIP. The percent difference of the VIP volume data with respect to the ILD data is -47.0 in Lane 4 averaged over the afternoon rush-hour period. The percent difference for the occupancy is -44.7 in Lane 4. Lane 1 (the leftmost freeway lane designated for general traffic) displayed the greatest percent differences, apparently from the effects of vehicle image projection on the VIP measurements.[7] The Lane 1 ILD suspect data or detector malfunction reports from earlier in the afternoon also cast some uncertainty into the accuracy of the ILD data.

7. Lane 1 ILD data were not available for the morning rush hour run. Thus, Lane 3 data were reported to have the largest percent difference for the morning run.

4.9.6 Jamboree Road PM Rush Hour Occupancy and Volume Data for 3/11/98

Figures J-36 to J-40 display the March 11, 1998 afternoon rush hour lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 5, respectively, of the I-5 mainline at the Jamboree Road site. These data were acquired from 15:15 to 19:00 hours. In this afternoon run, much of the Lane 5 VIP data were reported as good by the170 computer as shown in Table J-11. In the Jamboree Road morning runs that are discussed in later sections, the Lane 5 VIP data were generally not reported as being reliable. In order to allow comparisons among the morning and afternoon Jamboree Road evaluations, the data summaries that appear later in this section include tabulations for two sets of “all lane” good data. The first set for Lanes 1, 3, and 4 is used to compare with the morning runs, and the second set that includes Lanes 1, 3, 4, and 5 is used for comparisons among the afternoon sets. The Lane 2 ILDs were malfunctioning during this run as noted in Table J-12. Lane 1 and Lane 3 through 5 data in Figures J-36 and J-38 through J-40, respectively, show that the ILD and VIP lane occupancies and volumes generally track one another over time. There appears to be a greater difference between the lane volumes between 15:15 and 16:15 hours than during later portions of the run.

Figure J-41 compares the average occupancy and total volume measured by the ILDs and VIP on mainline Lanes 1, 3, and 4 as a function of time. The two sets of ILD and VIP values track one another. Figure J-42 displays the averages of the lane occupancy and total volume reported by the ILDs and VIP. Data are shown for each lane and for Lanes 1, 3, and 4 combined and Lanes 1, 3, 4, and 5 combined. The average occupancies in Figure J-42a are not very different when the Lane 5 data are included in the combined average. Figure J-43 shows the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 1, 3, and 4 combined and Lanes 1, 3, 4, and 5 combined. The percent difference between ILD and VIP volume measurement for Lane 5 (the lane closest to the surveillance trailer and camera) is smallest, equal to -32.4 (indicating moderate VIP overcounting). The Lane 5 percent difference for occupancy is 14.1, also the smallest value in the data set. The inclusion of Lane 5 data did not significantly change the percent difference between ILD and VIP volume measurements (-46.4 versus -49.8), but had more of an impact on occupancy measurements (-8.6 versus -21.0).

4.9.7 Jamboree Road AM Rush Hour Occupancy and Volume Data for 3/12/98

Figures J-44 to J-48 compare the Jamboree Road lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 5 of the I-5 mainline for the 6:15 to 9:30 morning rush hours on March 12, 1998. The 170 computer that processed the VIP detector inputs reported a malfunction during the acquisition or processing of most of the Lane 5 VIP data as shown in Table J-13. The Lane 5 ILD data in Table J-14 appear proper during the recording interval. The 170 computer did not process Lane 2 ILD data, apparently because the Lane 2 inductive loops were malfunctioning. To avoid biasing of the results, none of the Lane 2 and Lane 5 data are included in the summary plots later in this section. Figures J-44 and J-46 through J-48 show that the ILD and VIP lane occupancies and volumes generally track one another over time.

Figure J-49 compares the average occupancy and total volume measured by the ILDs and VIP on mainline Lanes 1, 3, and 4 as a function of time. The two sets of ILD and VIP values track one another well. Figure J-50 displays the averages of the lane occupancy and total volume reported by the ILDs and VIP during the morning rush hour interval. Data are shown for each lane and for Lanes 1, 3, and 4 combined (the lanes reporting good data for both the ILDs and VIP). Figure J-51 shows the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 1, 3, and 4 combined. The VIP occupancies have a smaller percent difference with respect to the ILD occupancies, than do the VIP lane volumes compared with the ILD lane volumes for the lanes reported. For Lane 4 (the closest lane to the trailer with good data), the percent difference in the volume measurements is -19.7 (indicating moderate VIP overcounting) and in the occupancy measurements is 14.4. Over the sum of Lane 1, 3, and 4 data, the percent difference for volume is -24.1 and that for occupancy is 15.9.

4.9.8 Jamboree Road PM Rush Hour Occupancy and Volume Data for 3/12/98

Figures J-52 to J-56 display the March 12, 1998 15:15 to 19:00-hour afternoon rush interval lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 5 at the Jamboree Road site. In this run, more of the Lane 5 VIP data were reported as good by the170 computer as shown in Table J-15. Therefore, the summaries that appear later in this section include tabulations for two sets of "all lane" good data, namely a set for Lanes 1, 3, and 4 to compare with the morning run, and a set that includes Lanes 1, 3, 4, and 5 to compare with other afternoon runs. The Lane 2 ILDs were malfunctioning during this run as well as seen in Table J-16. Lane 1 data in Figure J-52 show that the ILD and VIP lane occupancies and volumes generally track one another over time. The Lane 3 and Lane 4 data in Figures J-54 and J-55 exhibit some divergence after approximately 18:00 hours.

Figure J-57 compares the average occupancy and total volume measured by the ILDs and VIP on mainline Lanes 1, 3, and 4 as a function of time. The two sets of ILD and VIP values track one another except for some divergence after approximately 18:00 hours. Figure J-58 displays the averages of the lane occupancy and total volume reported by the ILDs and VIP. Data are shown for each lane and for Lanes 1, 3, and 4 combined and Lanes 1, 3, 4, and 5 combined. The average occupancies in Figure J-58a are not very different when the Lane 5 data are included in the combined average. Figure J-59 shows the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 1, 3, and 4 combined and Lanes 1, 3, 4, and 5 combined. The percent difference between ILD and VIP volume measurement for Lane 5 (the lane closest to the surveillance trailer and camera) is smallest, equal to -10.3 (indicating small to moderate VIP overcounting). The Lane 5 percent difference for occupancy is 24.0, which is not the smallest value in this data set. In this run, Lane 3 had the smallest occupancy percent difference equal to -5.7. The inclusion of Lane 5 data did not significantly change the percent difference between ILD and VIP volume measurements (-34.8 versus -31.4), but had more of an impact on occupancy measurements (-8.2 versus -0.4).

4.9.9 Jamboree Road AM Rush Hour Occupancy and Volume Data for 3/13/98

The March 13, 1998 Jamboree Road lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 5 of the I-5 mainline are compared in Figures J-60 to J-64 as a function of time for the 6:15 to 9:45 morning rush hours. The 170 computer that processed the VIP detector inputs reported a malfunction during the acquisition or processing of most of the Lane 5 VIP data as shown in Table J-17. The Lane 5 ILD data in Table J-18 appear proper during the recording interval. Similarly, the 170 computer did not process Lane 2 ILD data, apparently because the Lane 2 inductive loops were malfunctioning. To avoid biasing of the results, none of the Lane 2 and 5 data are included in the summary plots later in this section. Figures J-60 and J-62 through J-64 show that the ILD and VIP lane occupancies and volumes generally track one another over time.

Figure J-65 compares the average occupancy and total volume measured by the ILDs and VIP on mainline Lanes 1, 3, and 4 as a function of time. The two sets of ILD and VIP values track one another well. Figure J-66 displays the averages of the lane occupancy and total volume reported by the ILDs and VIP during the morning rush hour interval. Data are shown for each lane and for Lanes 1, 3, and 4 combined (the lanes reporting good data for both the ILDs and VIP). Figure J-67 shows the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 1, 3, and 4 combined. The VIP occupancies have a smaller percent difference with respect to the ILD occupancies, than do the VIP lane volumes compared with the ILD lane volumes for the lanes reported. For Lane 4 (the closest lane to the trailer with good data), the percent difference in the volume measurements is -26.6 (indicating moderate VIP overcounting) and in the occupancy measurements is -6.5. Over the sum of Lane 1, 3, and 4 data, the percent difference for volume is -24.5 and that for occupancy is 0.1.

4.9.10 Jamboree Road PM Rush Hour Occupancy and Volume Data for 3/13/98

Figures J-68 to J-72 display the March 13, 1998 afternoon rush hour lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 5, respectively, of the I-5 mainline at the Jamboree Road site. These data were acquired from 15:15 to 19:00 hours. In this run, more of the Lane 5 VIP data were reported as good by the170 computer as shown in Table J-19. Therefore, the summaries that appear later in this section include tabulations for two sets of “all lane” data, namely Lanes 1, 3, and 4 to compare with the morning run, and Lanes 1, 3, 4, and 5 to compare with the afternoon runs. The Lane 2 ILDs were malfunctioning during this run as seen in the Table J-20 data. The Lane 1 data in Figure J-68 show that the ILD and VIP lane occupancies and volumes generally track one another over time. The Lane 3 and Lane 4 data in Figures J-70 and J-71 exhibit some divergence after approximately 18:00 hours.
Figure J-73 compares the average occupancy and total volume measured by the ILDs and VIP on mainline Lanes 1, 3, and 4 as a function of time. The two sets of ILD and VIP values track one another except for some divergence after approximately 18:00 hours. Figure J-74 displays the averages of the lane occupancy and total volume reported by the ILDs and VIP. Data are shown for each lane and for Lanes 1, 3, and 4 combined and Lanes 1, 3, 4, and 5 combined. The average occupancies in Figure J-74a are not very different when the Lane 5 data are included in the combined average. Figure J-75 shows the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 1, 3, and 4 combined and Lanes 1, 3, 4, and 5 combined. The percent difference between ILD and VIP volume measurement for Lane 5 (the lane closest to the surveillance trailer and camera) is smallest, equal to -29.6 (indicating a moderate amount of VIP overcounting). The Lane 5 percent difference for occupancy is 11.3, which is not the smallest value. In this run, Lane 1 had the smallest occupancy percent difference equal to -8.9. The inclusion of Lane 5 data did not significantly change the percent difference between ILD and VIP

volume measurements (-39.2 versus -37.8), but had more of an impact on occupancy measurements (-16.0 versus -8.7).

4.9.11 Grand Avenue AM Rush Hour Occupancy and Volume Data for 4/14/98

The April 14, 1998 Grand Avenue lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 5 of the I-5 mainline are compared in Figures J-76 to J-80, respectively, for the 6:15 to 9:30 morning rush hours. Most of the Lane 5 VIP data are good in this run, as shown in Table J-21. The ILD data appear in Table J-22. Figures J-76 through J-80 show that the ILD and VIP lane occupancies and volumes generally track one another over time.

Figure J-81 compares the average occupancy and total volume measured by the ILDs and VIP on mainline Lanes 1, 2, 3, and 4 as a function of time. The two sets of ILD and VIP values track one another well. Figure J-82 displays the averages of the lane occupancy and total volume reported by the ILDs and VIP during the morning rush hour interval. Data are shown for each lane and for Lanes 1 through 4 combined and Lanes 1 through 5 combined. The average occupancies in Figure J-82a are not very different when the Lane 5 data are included in the combined average. Figure J-83 shows the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 1 through 4 combined and Lanes 1 through 5 combined. The VIP occupancies over the combined lanes have a smaller percent difference with respect to the ILD occupancies, than do the VIP lane volumes compared with the ILD lane volumes for the combined lanes. Lane 5 has larger percent differences than do any of the other individual lanes. One explanation is that the VIP detectors in Lane 5 may not have been functioning properly as evidenced by the reporting of suspect data or a malfunction for some of the Lane 5 recording periods. The other lanes produced percent occupancy and volume differences between –12.1 and 18 (in the small to moderate range). In fact, over Lanes 1, 2, 3, and 4, the percent difference for volume averages to 12.7 (indicating small undercounting by the VIP) and that for occupancy to -4.7.

4.9.12 Grand Avenue PM Rush Hour Occupancy and Volume Data for 4/14/98

Figures J-84 to J-88 display the April 14, 1998 afternoon rush hour lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 5, respectively, of the I-5 mainline at the Grand Avenue site. These data were acquired from 14:45 to 19:00 hours. Table J-23 shows that all of the Lane 5 VIP data were reported as good by the170 computer. Therefore, the summaries that appear later in this section include all the data from Lanes 1 through 5. The ILD data are given in Table J-24. Figures J-84 through J-88 show that the ILD and VIP lane volumes generally track one another over time. The ILD lane occupancies are larger than the VIP-measured occupancies between about 15:00 and 16:00 hours and between about 17:00 hours and 18:00 hours.

Figure J-89 compares the average occupancy and total volume measured by the ILDs and VIP on all mainline Lanes 1 through 5 as a function of time. As in the individual lane plots, the ILD and VIP volumes track one another, but the occupancy plot shows some divergence between about 15:00 and 16:00 hours and between about 17:00 hours and 18:00 hours. Figure J-90 displays the averages of the lane occupancy and total volume reported by the ILDs and VIP. Data are shown for each lane and for Lanes 1 through 5 combined. There is not much difference between the individual lane values and the combined values of the occupancies. Figure J-91 shows the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 1 through 5 combined. The percent difference between ILD and VIP volume measurement for Lane 5 (the lane closest to the surveillance trailer and camera) is smallest, equal to 2 (indicating a very small VIP undercount). The Lane 5 percent difference for occupancy is 28.4, the smallest value for all the lanes monitored.

4.9.13 Grand Avenue AM Rush Hour Occupancy and Volume Data for 4/16/98

Figures J-92 to J-96 compare the April 16, 1998 Grand Avenue lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 5, respectively, of the I-5 mainline for the 6:15 to 9:30 morning rush hours. Most of the Lane 5 VIP data are good in this run, as shown in Table J-25. The ILD data appear in Table J-26. Figures J-92 through J-96 show that the ILD and VIP lane occupancies and volumes generally track one another well over time.

Figure J-97 displays the average occupancy and total volume measured by the ILDs and VIP on mainline Lanes 1, 2, 3, and 4 as a function of time. The two sets of ILD and VIP values track one another well. Figure J-98 contains the averages of the lane occupancy and total volume reported by the ILDs and VIP during the morning rush hour interval. Data are shown for each lane and for Lanes 1 through 4 combined and Lanes 1 through 5 combined. The average occupancies in Figure J-98a are not very different when the Lane 5 data are included in the combined average. Figure J-99 shows the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 1 through 4 combined and Lanes 1 through 5 combined. The VIP occupancies over the combined lanes have a smaller percent difference with respect to the ILD occupancies, than do the VIP lane volumes compared with the ILD lane volumes for the combined lanes. Lane 5 has larger percent differences than do any of the other individual lanes. One explanation is that the VIP detectors in Lane 5 may not have been functioning properly as evidenced by the reporting of suspect data or a malfunction for some of the Lane 5 recording periods. The other lanes produced moderate percent occupancy and volume differences between –16.1 and 17.6. These are comparable to the values obtained in the April 14 run. In fact, over Lanes 1, 2, 3, and 4, the percent difference for volume averages to 11.3 (indicating small undercounting by the VIP) and that for occupancy to -3.7.

4.9.14 Grand Avenue PM Rush Hour Occupancy and Volume Data for 4/16/98

Figures J-100 to J-104 display the April 16, 1998 afternoon rush hour lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 5 of the I-5 mainline at the Grand Avenue site. These data were acquired between 16:30 and 19:00 hours. Table J-27 shows that all of the Lane 5 VIP data in this run were reported as good by the170 computer. Therefore, the summaries that appear later in this section include all the data from Lanes 1 through 5. The ILD data are given in Table J-28. Figures J-100 through J-104 show that the ILD and VIP lane volumes generally track one another over time. The ILD lane occupancies are larger than the VIP-measured occupancies between about 17:30 hours and 18:30 hours. This same effect was seen in the April 14 data.

Figure J-105 compares the average occupancy and total volume measured by the ILDs and VIP for Lanes 1 through 5 combined as a function of time. As in the individual lane plots, the ILD and VIP volumes track one another, but the occupancy plot shows some divergence between about 17:30 hours and 18:30 hours. Figure J-106 displays the averages of the lane occupancy and total volume reported by the ILDs and VIP. Data appear for each lane and for Lanes 1 through 5 combined. There is not much difference between the individual lane values and the combined values of the occupancies. Figure J-107 shows the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 1 through 5 combined. The percent difference between ILD and VIP volume measurement for Lane 4 is smallest in this run equal to 2.2 (indicating a very small VIP undercount). The Lane 5 percent difference for occupancy is 26.0, the smallest value for all the lanes monitored. The Lane 5 difference for volume is 7.8, indicating a small VIP undercount.

4.9.15 Summary of Mainline Occupancy and Volume Measurements

Table 4-11 summarizes the percent differences between the ILD and VIP total volume and average occupancy measurements for the runs made at each evaluation site. The data shown are over all lanes reporting good data. For Tustin Ranch Road, the good lanes were Lanes 2 through 4; for Jamboree Road, Lanes 1, 3, and 4; and for Grand Avenue, all lanes (Lanes 1 through 5). The Grand Avenue site had the smallest percent differences between ILD and VIP-measured mainline volumes. In morning runs the VIP undercounted at Grand Avenue, while in afternoon runs it overcounted. Additional data can be acquired to establish if there is significance to this pattern. (One potential explanation may be the presence of shadows in the afternoon.) By contrast, the VIP overcounted during both the morning and afternoon runs at the Tustin Ranch Road and Jamboree Road sites.

Table 4-11. Percent differences between ILD and VIP volumes and occupancies by evaluation site and time of day

Site	Time	Date	% Difference in Volume	% Difference in Occupancy
Tustin Ranch Road[1]	AM	3/5/98	-44.4	-10.8
	AM	3/9/98	-50.0	-10.3
	PM	3/9/98	-50.6	-53.2
	AM	3/10/98	-48.6	-10.8
	PM	3/10/98	-53.0	-49.4
Jamboree Road[2]	PM	3/11/98	-49.8	-21.0
	AM	3/12/98	-24.1	+15.9
	PM	3/12/98	-34.8	-8.2
	AM	3/13/98	-24.5	+0.1
	PM	3/13/98	-39.2	-16.0
Grand Avenue[3]	AM	4/14/98	+13.8	-1.2
	PM	4/14/98	-14.8	+34.1
	AM	4/16/98	+12.3	-4.2
	PM	4/16/98	-8.1	+27.1

1. Tustin Ranch Road data are for Lanes 2 through 4.
2. Jamboree Road data are for Lanes 1, 3, and 4.
3. Grand Avenue data are for Lanes 1 through 5.

Table 4-12a and Table 4-12b contain the average and standard deviation of the lane occupancies and volumes measured in the seven morning and seven afternoon runs by the ILDs and VIP. Table 4-12a shows the values for Lanes 1 through 3. Table 4-12b shows the values for Lanes 4 and 5 and the combination of all lanes reporting good data.

Table 4-12a. Average and standard deviation of occupancies and volumes as measured by the ILDs and VIP over Lanes 1 through 3 at all the evaluation sites

Statistic	Lane 1				Lane 2				Lane 3			
	ILD Occ	VIP Occ	ILD Vol	VIP Vol	ILD Occ	VIP Occ	ILD Vol	VIP Vol	ILD Occ	VIP Occ	ILD Vol	VIP Vol
Average	19.0	17.3	396	476	21.2	20.9	446	564	18.8	18.7	381	512
Std Dev	10.2	5.6	78	62	10.6	4.9	75	143	9.9	5.2	58	116

Table 4-12b. Average and standard deviation of occupancies and volumes as measured by the ILDs and VIP over Lanes 4 and 5 and the combination of all lanes reporting good data at all the evaluation sites

Statistic	Lane 4				Lane 5				All Lanes			
	ILD Occ	VIP Occ	ILD Vol	VIP Vol	ILD Occ	VIP Occ	ILD Vol	VIP Vol	ILD Occ	VIP Occ	ILD Vol	VIP Vol

Average	17.4	16.3	372	465	14.2	10.9	317	325	18.1	17.8	1336	1676
Std Dev	9.3	4.9	68	121	7.1	5.2	45	48	9.2	5.1	334	278

Figures 4-22 and 4-23 display the averages of the ILD and VIP-measured mainline occupancy and volume data in graphical form. The numbers near the bars are the average values that appear in Table 4-12.

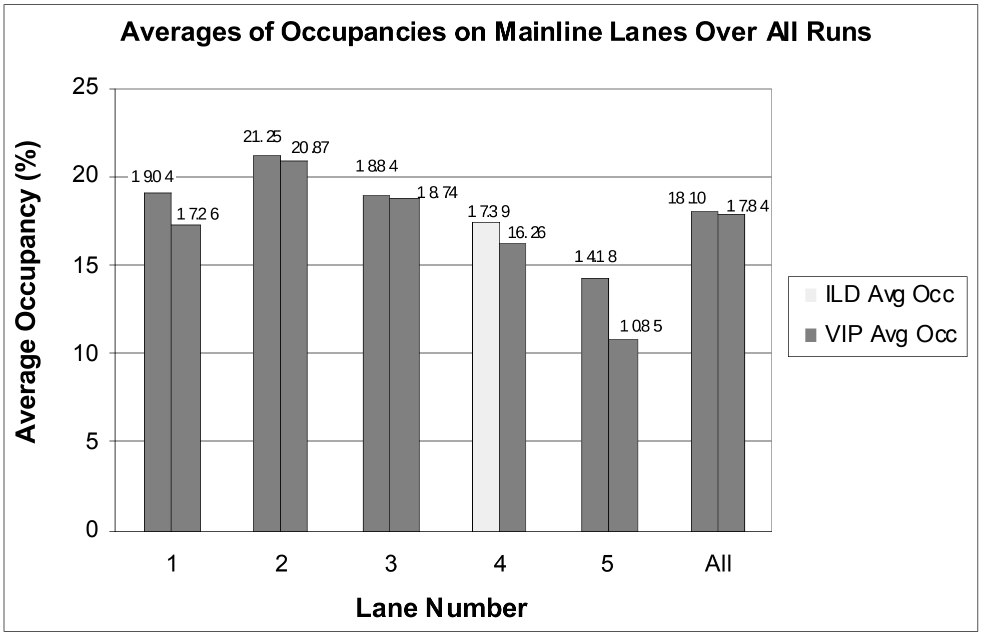

Figure 4-22. Average mainline occupancies over all runs as measured by the ILDs and VIP

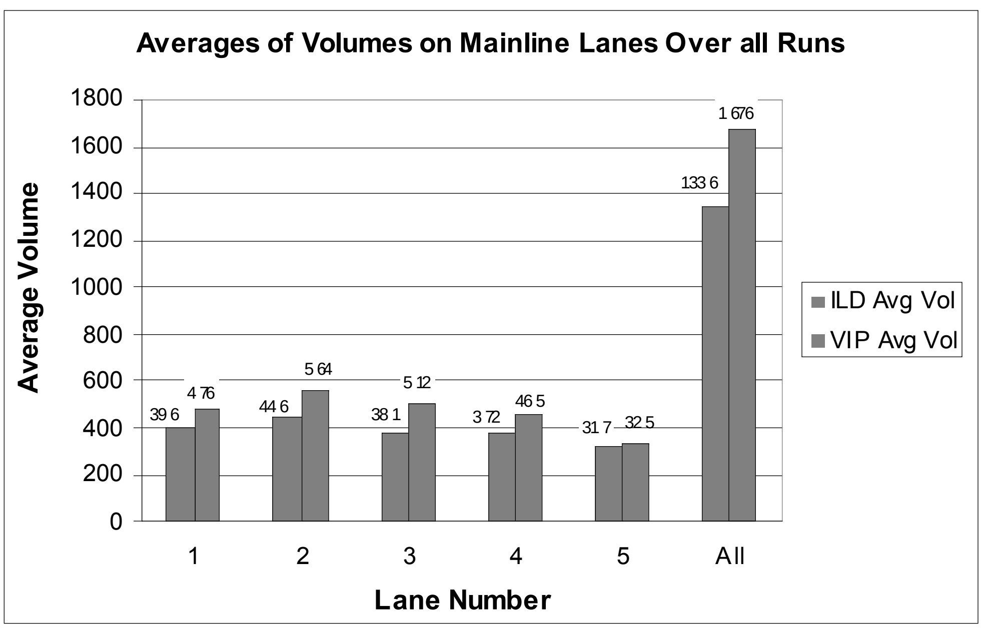

Figure 4-23. Average mainline volumes over all runs as measured by the ILDs and VIP

Figure 4-24 shows the averages of the percent differences between the ILD and VIP-measured average lane occupancies and total volumes for the fourteen runs. Lane 5, the lane closest to the shoulder, had the smallest percent difference in measured volume equal to –2.6 percent. The negative sign indicates that the VIP counted more vehicles than the ILD. Lane 3 had the smallest difference in occupancy measurement equal to 0.5 percent. The average percent differences in occupancy and volume over all lanes reporting good data were 8 and -22, respectively. The ability of the VIP to provide data with sufficient accuracy for the ramp-metering function is discussed in Section 4.10.

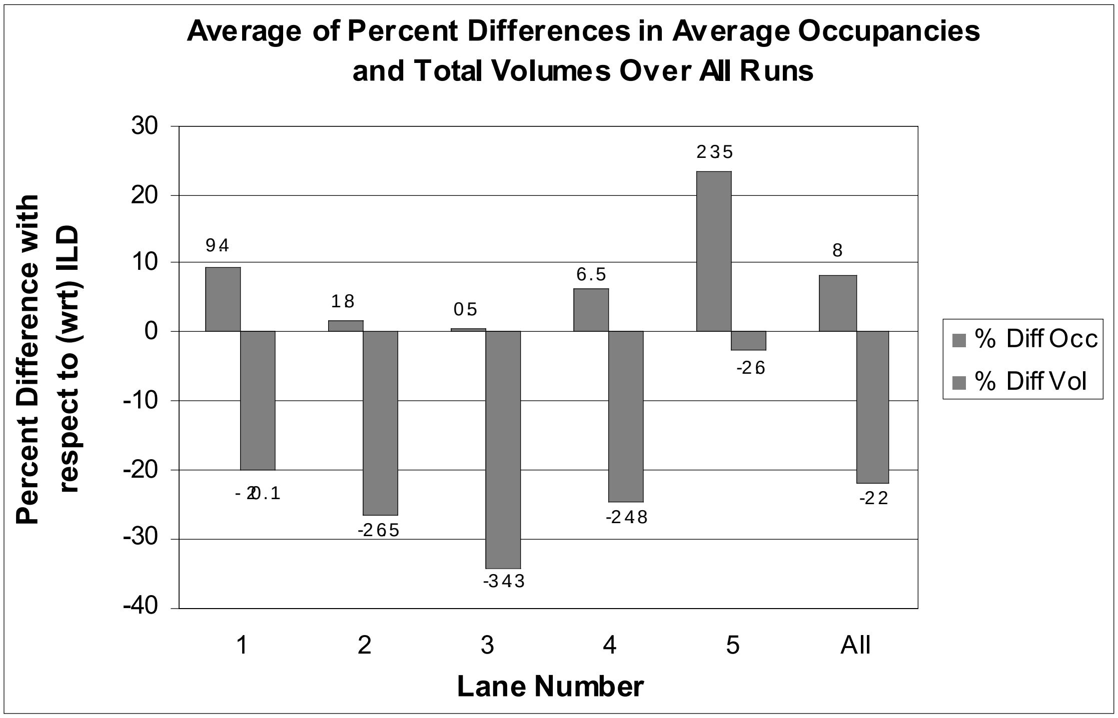

Figure 4-24. Average of the percent difference between the average occupancies and total volumes over all runs as measured by the ILDs and VIP

4.9.16 AutoScope Measurement Accuracy With More Ideal Camera Mounting

When the camera supplying imagery to the AutoScope is mounted over the center of a roadway at a minimum of 30 feet (9.1 meters) or at the side of a roadway at heights of 50 to 60 feet (15.2 to 18.3 meters), the volume, occupancy, and speed measurement accuracies are greater and, generally, meet the manufacturer's specifications shown in Table 4-13.[8,9,10]

8. AutoScope Consultant's Designer Guide, Econolite Control Products, Anaheim, CA.
9. Detection Technology for IVHS Final Report, Lawrence A. Klein, Principal Investigator, Hughes Aircraft Company, FHWA Report Number FHWA-RD-95-100, July 1995.
10. Field Test of Monitoring of Urban Vehicle Operations Using Non-Intrusive Technologies Final Report, MnDOT, FHWA Report Number FHWA-PL-97-018, May 1997.

Table 4-13. AutoScope measurement accuracies under more ideal camera mounting

Lane Occupancy Error	Volume Flow Range and Error	Speed Range and Error	Mounting Height and Details
Not specified by manufacturer. Some measured data available that indicate ≈1-3% errors under ideal conditions.	≤ 4% day and night with centered, high camera without occlusion. <7% with artifacts such as shadows, fog, rain, snow.	Not specified. Experience shows ± 7% when measuring speed of an individual vehicle, ± 1% when measuring speed over a 15-minute interval.	30 ft (9.1 m) minimum for side-mounted camera. Monitoring of 6-8 lanes may require camera to be mounted over the traveled lanes. Greater height provides more accurate speed measurement and less occlusion of multiple-lane traffic flow by tall vehicles. Cameras mounted over center of lanes can be lower than side-mounted cameras.

4.10 Rush Hour Metering Rate Data Analysis

The following sections describe the metering rate and ramp demand results obtained at each morning and afternoon evaluation run at which 170-controller polling data were recorded on the laptop computers.

4.10.1 Tustin Ranch Road AM Rush Hour Metering Rate Data for 3/5/98

Figure J-108 shows results from the Tustin Ranch Road site for the morning rush hour interval on March 5, 1998. It compares the ramp meter rate used, the local responsive (LR) rate, and the TOD rate computed from the ILD and VIP measurement data. The ILD and VIP data output from the 170 controllers appear in Tables J-29 and J-30. The TOD rates in Figure J-108c indicate that the 170 controllers connected to the ILDs and VIP were programmed with different rates. The different rates appear in the ILD and VIP TOD graph (Figure J-108c) and the ramp meter rate used graph (Figure J-108a). The ILD and VIP LR rates in Figure J-108b appear identical over most of the rush hour interval. The differences in LR rates at the beginning and end of the data-recording period are attributable to initialization and data interruptions that occur during the start and end of a run.

Figure J-109a shows ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. Only values for which both ILD and VIP data are reported as good are plotted. The ILD and VIP value pairs for occupancy and volume track one another.

The percent differences between the ILD-computed and VIP-computed ramp demand occupancy and volume are shown in Figure J-109b. The –7 percent difference in ramp demand occupancy is in the small range, while the 1 percent difference in ramp demand volume is insignificant. The -44.4 percent difference in ILD and VIP mainline volume measurements over the combination of Lanes 2 through 4 (reported in Section 4.9.1) appears adequate for calculating local responsive ramp meter rates (from the VIP measurements) that are, for the most part, identical to the rates calculated from the ILDs.

4.10.2 Tustin Ranch Road AM Rush Hour Metering Rate Data for 3/9/98

Figure J-110 compares the ramp meter rate used, the LR rate, and the TOD rate as computed from the ILD and VIP measurement data acquired at the Tustin Ranch Road site during the morning rush hour interval on March 9, 1998. The ILD and VIP data output from the 170 controllers appear in Tables J-31 and J-32. The time-of-day rates in Figure J-110c indicate that the 170 controllers connected to the ILDs and VIP were programmed with different TOD rates. The different rates appear in the ILD and VIP TOD graph (Figure J-110c) and the ramp meter rate used graph (Figure J-110a). The ILD and VIP LR rates in Figure J-110b appear identical over most of the rush hour interval. The differences in LR rates at the beginning and end of the data-recording period are attributable to initialization and data interruptions that occur during the start and end of a run. The VIP-calculated LR rate of 8 vehicles/minute at 6:45 is the only intermediate point at which the VIP and ILD LR rates are not the same.
Figure J-111a shows ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. Only values for which both ILD and VIP data are reported as good are plotted. The ILD and VIP values for occupancy and volume track one another.

The percent differences between the ILD-computed and VIP-computed ramp demand occupancy and volume are given in Figure J-111b. The –15 percent difference in ramp demand occupancy is in the moderate range, while the 36 percent difference in ramp demand volume is significant. The small percent difference of 2.7 in ILD and VIP mainline volume measurements, as reported for the combination of Lanes 2 through 4 in Section 4.9.2, produces local responsive ramp meter rates (from the VIP measurements) that are, for the most part, identical to the rates calculated from the ILDs.

4.10.3 Tustin Ranch Road PM Rush Hour Metering Rate Data for 3/9/98

Figure J-112 compares the ramp meter rate used, the LR rate, and the TOD rate as computed from the ILD and VIP measurement data acquired at the Tustin Ranch Road site during the afternoon rush hour interval on March 9, 1998. The ILD and VIP data output from the 170 controllers appear in Tables J-33 and J-34. The time-of-day rates in Figure J-112c indicate that the 170 controllers connected to the ILDs and VIP were programmed with different rates. The different rates appear in the ILD and VIP TOD graph (Figure J-112c) and the ramp meter rate used graph (Figure J-112a). The ILD-produced LR rates in Figure J-112b appear erratic.

Figure J-113a shows ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. Only values for which both ILD and VIP data are reported as good are plotted. The two sets of values in the figure indicate the same trends over time.

The percent differences between the ILD and VIP ramp demand occupancy and volume are given in Figure J-113b. The –31 percent difference in ramp demand occupancy is in the significant range, while the 23 percent difference in ramp demand volume is moderate. It is difficult to establish the effects of the ILD and VIP measurement differences in mainline volume on LR meter rate because of the erratic LR rate behavior described above.

4.10.4 Tustin Ranch Road AM Rush Hour Metering Rate Data for 3/10/98

Figure J-114 compares the ramp meter rate used, the LR rate, and the TOD rate computed from the ILD and VIP measurement data acquired at the Tustin Ranch Road site during the morning rush hour interval on March 10, 1998. The ILD and VIP data output from the 170 controllers appear in Tables J-35 and J-36. Examination of the time-of-day rate in Figure J-114c indicates that the 170 controllers connected to the ILDs and VIP were programmed with different TOD rates. This accounts for the differences seen in the TOD graph (Figure J-114c) and the ramp meter rate used graph (Figure J-114a). The ILD and VIP LR rates in Figure J-114b appear identical over most of the rush hour interval. The differences in LR rates at the beginning of the data-recording period are attributable to initialization and data interruptions that occur during the start of a run.

Figure J-115a shows ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. Only values for which both ILD and VIP data are reported as good are plotted. The ILD and VIP values for occupancy and volume track one another.

The percent differences between the ILD and VIP ramp demand occupancy and volume are given in Figure J-115b. The –23 percent difference in ramp demand occupancy is in the moderate range, while the 37 percent difference in ramp demand volume is significant. Even the significant –53.0 percent difference in the Lane 2 through 4 mainline volume ILD and VIP measurements, shown in Figure J-28, produces local responsive ramp meter rates (from the VIP measurements) that are identical to the rates calculated from the ILDs (with the exception of the beginning of the run).

4.10.5 Tustin Ranch Road PM Rush Hour Metering Rate Data for 3/10/98

Figure J-116 compares the ramp meter rate used, the LR rate, and the TOD rate as computed from the ILD and VIP measurement data acquired at the Tustin Ranch Road site during the afternoon rush hour interval on March 10, 1998. The ILD and VIP data output from the 170 controllers appear in Tables J-37 and J-38. The time-of-day rates in Figure J-116c indicate that the 170 controllers connected to the ILDs and VIP were programmed with different TOD rates. The different rates appear in the ILD and VIP TOD graph (Figure J-116c) and the ramp meter rate used graph (Figure J-116a). The ILD-produced LR rates in Figure J-116b again appear erratic. This behavior was also observed during the afternoon run on March 9.

Figure J-117a shows ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. Only values for which both ILD and VIP data are reported as good are plotted. In this run, there were only two data points that met this criterion.

The percent differences between the ILD and VIP ramp demand occupancy and volume are given in Figure J-117b. The –18 percent difference in ramp demand occupancy and 29 percent difference in ramp demand volume are in the moderate range. Not much significance should be attributed to the ramp demand parameter calculations, however, since they are based on only two data points. It is difficult to establish the effects of the ILD and VIP measurement differences in mainline volume on LR meter rate because of the erratic LR rate behavior described above.

4.10.6 Jamboree Road PM Rush Hour Metering Rate Data for 3/11/98

Figure J-118 shows results from the Jamboree Road site for the afternoon rush hour interval on March 11, 1998. It compares the ramp meter rate used, the local responsive (LR) rate, and the TOD rate as computed from the ILD and VIP measurement data. The

ILD and VIP data output from the 170 controllers appear in Tables J-39 and J-40. The time-of-day rates in Figure J-118c indicate that the 170 controllers connected to the ILDs and VIP were programmed with different rates. This accounts for the rate differences in the TOD plot (Figure J-118c) and most of the differences in the ramp meter rate used plot (Figure J-118a). The ILD-produced LR rates in Figure J-118b appear erratic. The same phenomenon was observed in the Tustin Ranch Road afternoon runs on March 9 and 10. The erratic behavior also appeared in the ramp meter rate used plot on March 11.

Figure J-119a shows ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. Only values for which both ILD and VIP data are reported as good are plotted. The two sets of values in the figure indicate the same trends over time.

The percent differences between the ILD and VIP ramp demand occupancy and volume are given in Figure J-119b. The ILD and VIP ramp demand occupancy measurements have an insignificant -1 percent difference. It is difficult to establish the effects of the ILD and VIP measurement differences in mainline volume on LR meter rate because of the erratic LR rate behavior described above.

4.10.7 Jamboree Road AM Rush Hour Metering Rate Data for 3/12/98

Figure J-120 compares the ramp meter rate used, the LR rate, and the TOD rate as computed from the ILD and VIP measurement data acquired at the Jamboree Road site during the morning rush hour interval on March 12, 1998. The ILD and VIP data output from the 170 controllers appear in Tables J-41 and J-42. Examination of the time-of-day rate in Figure J-120c indicates that the 170 controllers connected to the ILDs and VIP were programmed with different TOD rates. This accounts for the differences seen in the TOD graph (Figure J-120c) and the ramp meter rate used graph (Figure J-120a). The ILD and VIP LR rates in Figure J-120b appear identical over most of the rush hour interval. The differences in LR rates at the beginning and end of the data-recording period are attributable to initialization and data interruptions that occur during the start and end of a run.

Figure J-121a shows ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. Only values for which both ILD and VIP data are reported as good are plotted. The only data that do not track one another in Figures J-121a are the ramp demand ILD and VIP volumes indicated by the triangle and cross symbols in Figure J-121a.

The percent differences between the ILD and VIP ramp demand occupancy and volume are given in Figure J-121b. The ILD and VIP ramp demand occupancy measurements have a zero percent difference. The ramp demand volume measurements yield a -18 percent difference, indicating moderate overcounting by the VIP. Even the moderate -24.1 percent difference in ILD and VIP mainline volume measurements over the combination of Lanes 1, 3, and 4, shown in Figure J-51, produces local responsive ramp meter rates (from the VIP measurements) that are identical to the rates calculated from the ILDs (with the exception of the beginning and end of the run).

4.10.8 Jamboree Road PM Rush Hour Metering Rate Data for 3/12/98

Figure J-122 compares the ramp meter rate used, the LR rate, and the TOD rate as computed from the ILD and VIP measurement data acquired at the Jamboree Road site during the afternoon rush hour interval on March 12, 1998. The ILD and VIP data output from the 170 controllers appear in Tables J-43 and J-44. The time-of-day rates in Figure J-122c indicate that the 170 controllers connected to the ILDs and VIP were programmed with different TOD rates. This accounts for the differences seen in the TOD plot (Figure J-122c) and the ramp meter rate used plot (Figure J-122a). The ILD-produced LR rates in Figure J-122b appear erratic. The same phenomenon was observed in the Tustin Ranch Road afternoon runs on March 9 and 10.

Figure J-123a shows ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. Only values for which both ILD and VIP data are reported as good are plotted. The ILD and VIP value pairs for occupancy and volume indicate the same trends over time.

The percent differences between the ILD and VIP ramp demand occupancy and volume are given in Figure J-123b. The ILD and VIP ramp demand occupancy measurements have an insignificant 1 percent difference. The ramp demand volume measurement difference of -19 percent indicates moderate overcounting by the VIP. It is difficult to establish the effects of the ILD and VIP measurement differences in mainline volume on LR meter rate because of the erratic LR rate behavior described above.

4.10.9 Jamboree Road AM Rush Hour Metering Rate Data for 3/13/98

Figure J-124 compares the ramp meter rate used, the LR rate, and the TOD rate computed from the ILD and VIP measurement data acquired at the Jamboree Road site during the morning rush hour interval on March 13, 1998. The ILD and VIP data output from the 170 controllers appear in Tables J-45 and J-46. Examination of the time-of-day rate in Figure J-124c indicates that the 170 controllers connected to the ILDs and VIP were programmed with different TOD rates. This accounts for the differences seen in the TOD plot (Figure J-124c) and the ramp meter rate used plot (Figure J-124a). The ILD and VIP LR rates in Figure J-124b are identical between 7:00 and 8:00. The differences in LR rates at the beginning of the data-recording period are attributable to initialization and data interruptions that occur during the start of a run. Differences appear in the ILD and VIP LR rates toward the end of the run.

Figure J-125a shows ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. Only values for which both ILD and VIP data are reported as good are plotted. The ILD and VIP values for occupancy and volume track one another.

The percent differences between the ILD and VIP ramp demand occupancy and volume are given in Figure J-125b. The 4 percent difference in ramp demand occupancy is in the small range, while the -37 percent difference in ramp demand volume is significant. Even the moderate –24.5 percent difference between ILD and VIP mainline volume measurements over the combination of Lanes 1, 3, and 4 (shown in Figure J-67) is adequate to produce local responsive ramp meter rates (from the VIP measurements) that are identical to the rates calculated from the ILDs (with the exception of the beginning and end of the run).

4.10.10 Jamboree Road PM Rush Hour Metering Rate Data for 3/13/98

Figure J-126 compares the ramp meter rate used, the LR rate, and the TOD rate as computed from the ILD and VIP measurement data acquired at the Jamboree Road site during the afternoon rush hour interval on March 13, 1998. The ILD and VIP data output from the 170 controllers appear in Tables J-47 and J-48. The time-of-day rates in Figure J-126c indicate that the 170 controllers connected to the ILDs and VIP were programmed with different TOD rates. This accounts for the differences seen in the TOD plot (Figure J-126c) and the ramp meter rate used plot (Figure J-126a). The ILD-produced LR rates in Figure J-126b again appear erratic. This behavior was also observed during the March 11 and 12 afternoon run at Jamboree Road and in the Tustin Ranch Road afternoon runs on March 9 and 10. This “afternoon effect” bears further investigation.

Figure J-127a shows ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. This run produced a complete set of data for the afternoon recording interval. The ILD and VIP data indicate the same trends and, in fact, are within several percent of each other.

The percent differences between the ILD and VIP ramp demand occupancy and volume are given in Figure J-127b. The –5 percent difference in ramp demand occupancy is in the small range, while the -1 percent difference in ramp demand volume is insignificant. It is difficult to gauge the effects of the ILD and VIP measurement differences in mainline volume on LR meter rate because of the erratic LR rate behavior described above.

4.10.11 Grand Avenue AM Rush Hour Metering Rate Data for 4/14/98

Figure J-128 compares the ramp meter rate used, the local responsive (LR) rate, and the TOD rate as computed from the ILD and VIP measurement data acquired at the Grand Avenue site during the morning rush hour interval on April 14, 1998. The ILD and VIP data output from the 170 controllers appear in Tables J-49 and J-50. At this site, the 170 controllers connected to the ILDs and VIP were programmed with the same TOD rates (seen by the overlapping of the graphs in Figure J-128c) since a large queue was not created on the ramp during the data recording period of 6:15 through 9:15 hours. This programming also caused the ILD and VIP ramp meter rate used graphs to overlap as shown in the central portion of Figure J-128a. The ILD and VIP LR rates in Figure J-128b are identical in the middle of the run. The differences in LR rates at the beginning and end of the data-recording period are attributable to initialization and data interruptions that occur during the start and end of a run.

Figure J-129a shows ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. This run produced a complete set of data for the morning recording interval. The ILD and VIP data indicate the same trends and, in fact, are within several percent of each other.

The percent differences between the ILD and VIP ramp demand occupancy and volume are given in Figure J-129b. The ILD and VIP ramp demand occupancy measurements have a -4 percent difference. The ramp demand volume measurements yield a 3 percent difference, indicating small undercounting by the VIP. The 13.8 percent difference between ILD and VIP mainline volume measurements (reported in Figure J-83) produces local responsive ramp meter rates (from the VIP measurements) that are identical to the rates calculated from the ILDs (with the exception of the beginning and end of the run).

4.10.12 Grand Avenue PM Rush Hour Metering Rate Data for 4/14/98

Figure J-130 compares the ramp meter rate used, the LR rate, and the TOD rate as computed from the ILD and VIP measurement data acquired at the Grand Avenue site during the afternoon rush hour interval on April 14, 1998. The ILD and VIP data output from the 170 controllers appear in Tables J-51 and J-52. At this site, the 170 controllers connected to the ILDs and VIP were programmed with the same TOD rates (as seen in Figure J-130c) because a large queue was not created on the ramp during the data recording period of 14:45 through 19:00 hours. This programming accounts for the overlapping of the ILD and VIP data in most of the ramp meter rate used plot (Figure J-130a). The ILD and VIP LR rates in Figure J-130b are identical in the middle of the run. The differences in LR rates at the beginning and end of the data-recording period are mainly attributable to initialization and data interruptions that occur during the start and end of a run. There was a spike in the VIP LR rate, however, at 18:15 hours.

Figure J-131a displays ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. Only values for which both ILD and VIP data are reported as good are plotted. The two sets of values in the figure show, for the most part, the same trends over time. There is some erratic behavior in the VIP ramp demand volume as indicated by the data entries marked with a cross in Figure J-131a.

The percent differences between the ILD and VIP ramp demand occupancy and volume are given in Figure J-131b. The ILD and VIP ramp demand occupancy measurements have a small -3 percent difference. The ramp demand volume measurement difference of -80 percent indicates significant overcounting by the VIP. The –14.8 percent difference in ILD and VIP-measured mainline volume over all lanes (reported in Figure J-91) produces local responsive ramp meter rates (from the VIP measurements) that are identical to the rates calculated from the ILDs (with the exception of the beginning and end of the run and the one spike at 18:15 hours).

4.10.13 Grand Avenue AM Rush Hour Metering Rate Data for 4/16/98

Figure J-132 compares the ramp meter rate used, the LR rate, and the TOD rate computed from the ILD and VIP measurement data acquired at the Grand Avenue site during the morning rush hour interval on April 16, 1998. The ILD and VIP data output from the 170 controllers appear in Tables J-53 and J-54. At this site, the 170 controllers connected to the ILDs and VIP were programmed with the same TOD rates (as seen in Figure J-132c) since a large ramp queue was not formed during the run interval of 6:15 to 9:15 hours. This programming accounts for the overlapping of the ILD and VIP data in most of the ramp meter rate used plot (Figure J-132a). The ILD and VIP LR rates in Figure J-132b are identical in the middle of the run. The differences in LR rates at the beginning and end of the data-recording period are attributable to initialization and data interruptions that occur during the start and end of a run.

Figure J-133a shows ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. This run produced a complete set of data for the morning recording interval. The ILD and VIP data indicate the same trends and, in fact, are within several percent of each other.

The percent differences between the ILD and VIP ramp demand occupancy and volume are given in Figure J-133b. The 0.8 percent difference in ramp demand occupancy is insignificant, as is the –1.5 percent difference in ramp demand volume. The 12.3 percent difference in ILD and VIP-measured mainline volume over all lanes (shown in Figure J-99) produces local responsive ramp meter rates (from the VIP measurements) that are identical to the rates calculated from the ILDs (with the exception of the beginning and end of the run).

4.10.14 Grand Avenue PM Rush Hour Metering Rate Data for 4/16/98

Figure J-134 compares the ramp meter rate used, the LR rate, and the TOD rate as computed from the ILD and VIP measurement data acquired at the Grand Avenue site during the afternoon rush hour interval on April 16, 1998. The ILD and VIP data output from the 170 controllers appear in Tables J-55 and J-56. At this site, the 170 controllers connected to the ILDs and VIP were programmed with the same TOD rates (as seen in Figure J-134c) since a large ramp queue was not formed during the run interval of 16:30 and 19:00 hours. This programming accounts for the overlapping of the ILD and VIP data in most of the ramp meter rate used plot (Figure J-134a). The ILD and VIP LR rates in Figure J-134b are identical in the middle of the run. The differences in LR rates at the beginning and end of the data-recording period are attributable to initialization and data interruptions that occur during the start and end of a run.

Figure J-135a shows ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. Only values for which both ILD and VIP data are reported as good are plotted. The ILD and VIP data indicate the same trends and, in fact, are within several percent of each other.

The percent differences between the ILD and VIP ramp demand occupancy and volume are given in Figure J-135b. The –0.2 percent difference in ramp demand occupancy is insignificant. The 4 percent difference in ramp demand volume is small. The –8.1 percent difference in ILD and VIP-measured mainline volume (shown in Figure J-107) produces local responsive ramp meter rates (from the VIP measurements) that are identical to the rates calculated from the ILDs (with the exception of the beginning and end of the run).

4.10.15 Summary Comments Concerning Rush Hour Metering Rate Data

1. The ILD-produced LR 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.

2. The VIP data appear to be sufficiently accurate to adapt ramp meter rates to the real-time traffic volume and occupancy on the mainline. This is shown in the comparison of the LR 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 its lower limit.

3. However, 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 as was shown in Table 3-6. It is more likely that the VIP will overcount when the camera is mounted as it was in this evaluation.

4.11 Qualitative Data to Evaluate Utility of Surveillance Trailer Placement in a Construction Zone

Discussions took place with Caltrans and Anaheim during the Winter and Spring of 1998 to select a construction site that would be suitable to the two agencies. Both wanted a location near a freeway interchange that was under construction. Caltrans could use the video imagery to determine traffic queues and implement flush plans to clear intersections under their control. Anaheim could use the imagery in a similar manner. The site of choice was the I-5 interchange at Katella Avenue in Anaheim. It had Disneyland and Anaheim Convention Center traffic, freeway and arterial construction, and recurring peak-hour congestion. A surveillance trailer was brought there, but before it could become operational, it had to be moved because it interfered with the contractor's reconstruction activities. (The contractor had previously given permission to bring the trailer to this site.) It was more difficult to find a site where both a surveillance and ramp meter trailer could be situated. Three factors impacted a ramp-metering deployment. First, an analysis of traffic volume is required to find the controlling bottleneck on the freeway under construction. Ramp metering can then be applied upstream of the bottleneck. However, the survey takes personnel and monetary resources that are not readily available. Second, it is difficult to find real estate that can accommodate both trailers. This problem is exacerbated by the frequent realignment of the freeway in the construction area. Third, Caltrans prefers permanent to temporary metering devices to ensure driver acceptance and compliance.

Eventually a surveillance trailer was brought to Katella Way and I-5 as shown in Figure 4-25. The intent was to gather information about the trailer's use in an actual construction area. The Caltrans District 12 TMC personnel periodically ensured that the cameras and their scanning controls were operational, but did not really use the video imagery in traffic operations. It is believed, however, that the imagery from the cameras would have been used if an emergency developed in the area surveilled by the cameras.

(a) Rear view of trailer showing southbound I-5 and entrance ramp

(b) Katella Way entrance ramp showing surveillance trailer to left of ramp

Figure 4-25. Surveillance trailer location at southbound entrance to I-5 at Katella Way

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.

6. Recommendations

The major recommendations of the evaluators have been grouped into three categories as summarized below.

6.1 Planning and Policy

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 imagery and VIP data;

3. Contractors be allowed a more direct method of parts procurement, perhaps through a project credit card, for items costing less than some predetermined amount;

4. Schedules in future programs reflect the possibility for some added requirements and for testing of all subsystems prior to system integration;

5. Cutoff dates be established after which further requirements are not permitted to be added;

6. A clear delineation between the goals for a concept validation program versus a program to develop operational equipment be established;

7. Cost centers be created for all stakeholders to participate in the design and execution of future programs;

8. A regular trailer maintenance schedule be established and executed;

9. Additional personnel, especially engineers, be trained in operating and diagnosing causes of problems in the electrical and mechanical equipment in the trailers and TMC.

6.2 Technical

10. Problems with polling 170-controllers in the surveillance trailers and displaying their output data on TMC workstations be resolved;

11. A method of compensating for mainline vehicle overcount by the VIPs be developed in order to report valid mainline traffic volumes and levels of service;

12. A technique to ensure onramp vehicle presence detection approaching 100 percent be found.

6.3 Hardware Upgrades

13. The pan and tilt assembly used for the color surveillance cameras be replaced with a model that can support more weight;

14. Cables and wires that are associated with the security camera be enclosed in metal conduit;

15. Higher sensitivity color cameras be purchased for any future surveillance needs.

6.4 Optimization of Existing Equipment

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

17. Camera sun shields be moved as far forward as possible to minimize sun glint and rain from interfering with camera operation.

7. Reference Documents

The list below represents a partial compilation of documents prepared during the Mobile Surveillance and Wireless Communication Systems Field Operational Test. Other documents may be available in the project library at District 12.

1. *Functional Requirements Specifications*, Hughes Aircraft Company, Fullerton, CA.

2. *System Information Manual*, Hughes Aircraft Company, Fullerton, CA, Feb. 1998.

3. *Test Plans and Procedures* [*for System Acceptance Test*], Hughes Aircraft Company, Fullerton, CA, Oct. 1997.

4. Options for additional relay stations (memo and presentation formats), Hughes Aircraft Company, Fullerton, CA.

5. *Evaluation Plan for Mobile Surveillance and Wireless Communication Systems Field Operational Test*, Rev. 2.0, Pacific Polytechnic Institute, San Luis Obispo, CA, Mar. 1997.

6. *Individual Evaluation Plan for Interstate-5 Test*, Pacific Polytechnic Institute, San Luis Obispo, CA, Oct. 1996.

7. *Individual Evaluation Plan for City of Anaheim Test*, Pacific Polytechnic Institute, San Luis Obispo, CA, Mar. 1997.

8. *Evaluation Report for Mobile Surveillance and Wireless Communication Systems Field Operational Test*, Partial Draft, Pacific Polytechnic Institute, San Luis Obispo, CA, Jun. 1997. Also published by California Partners for Advanced Transit and Highways (PATH) under Report 97-C34, Richmond, CA, Nov. 1997.