CASE STUDIES OF MAINTAINING ITS DEVICES IN RURAL AREAS

Showcase Evaluation # 3

Final Report

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GLOSSARY OF ABBREVIATIONS

Caltrans	California Department of Transportation
CCTV	Closed Circuit Television
CMS	Changeable Message Sign
COATS	California/Oregon Advanced Transportation Systems
DMS	Dynamic Message Signs
ME	Electrical Maintenance
FEN	Field Element Network
FTE	Full Time Employees
HAR	Highway Advisory Radio
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
LAN	Local Area Network
LED	Light Emitting Diode
MP	Mile Post
NB	North Bound
ODOT	Oregon Department of Transportation
PM	Preventive Maintenance or Post Mile
PVMS	Portable Variable Message Signs
RWIS	Road Weather Information Systems
SB	South Bound
TMC	Traffic Management Center
TOC	Traffic Operations Center
VMS	Variable Message Sign
WAN	Wide Area Network
WTI	Western Transportation Institute

DEFINITIONS

Primary Downtime: The primary downtime is defined as the system downtime for reported problems for the purpose of this study. This was calculated to be the time period between the time a problem was reported and the time when the corresponding system was repaired to be fully or partially functional.

Preventive Maintenance Delay: The preventive maintenance delay is defined as the time period between the time a preventive maintenance activity was scheduled for and the time when the preventive maintenance activity was completed. This measure does not indicate any malfunction in the primary use of a field element because the maintenance activity is preventive in nature.

Maintenance Costs: The maintenance costs include the labor and equipment costs of attending to reported problems and performing preventive maintenance along with costs of replacing components of the field elements. The maintenance costs do not include the operational costs (i.e. power and communication utility expenses)

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1. INTRODUCTION

Critical to the long-term success of Intelligent Transportation Systems (ITS) deployment is the timely and appropriate maintenance of ITS elements. Proper maintenance can help to extend the useful life of the ITS infrastructure, reducing its long-term cost. Proper maintenance can also help to increase system reliability, making ITS elements more valuable to both travelers and system operators. On the other hand, malfunctioning ITS equipment can quickly harm the credibility of ITS investments, potentially reducing the savings in time, lives and money that may result from ITS deployment.

Despite the importance of ITS maintenance, previous studies done by the Western Transportation Institute (WTI) at Montana State University for the California and Oregon Departments of Transportation (Caltrans and ODOT) indicate that little research has been conducted into ITS maintenance issues (1, 2). Since many ITS deployments are relatively new, it may be that most maintenance is still covered by vendors through warranty agreements. As warranties expire, however, responsibility for ITS maintenance will return to the deploying agencies.

1.1. ITS Maintenance in Rural Areas

While maintenance challenges of ITS devices in rural areas are similar in urban and rural areas in some aspects, maintaining ITS devices in rural areas has additional challenges. While contracting ITS maintenance is becoming increasingly common in urban areas, contracting is less feasible and more expensive in rural areas, due to longer distances to the ITS sites and a relative shortage of firms qualified to perform ITS maintenance. As a result, rural transportation agencies may need to rely more heavily on their own resources and skills to perform maintenance. The distance and travel time between maintenance offices and field devices are usually significantly greater in rural areas. This is especially critical for maintenance activities requiring staff who have the necessary specialized training and who may not be available in every maintenance region within an agency.

WTI's previous research into ITS maintenance, cited earlier, focused on the issue primarily from a planning perspective. As more ITS technologies are deployed in the California/Oregon Advanced Transportation Systems (COATS) study area, there exists a rich repository of information on actual maintenance experience from Caltrans and ODOT, as well as other agencies that have deployed ITS in the COATS area. This experience may be useful in providing more accurate information on maintenance costs, lessons learned on how to improve maintainability of field devices in the design and procurement phases, and other information that could help to improve ITS maintenance for existing and future deployments. The comprehensive cost analysis using available archived data on ITS maintenance activities for selected technologies and locations in the COATS study area will help the state and federal agencies to plan for ITS maintenance in rural remote locations.

1.2. Study Objectives

The purpose of this project, funded through the bi-state COATS Showcase project, is to develop case studies of the maintenance of ITS in the COATS study area. These case studies provide lessons learned to guide future deployment of ITS in the COATS area specifically, and in rural environments in general. The purpose of the project is consistent with the following objectives of the COATS study effort:

- **Objective 1.1**: Provide sustainable traveler information systems that disseminate credible and accurate real-time information (emphasis added)

- **Objective 3.1**: Collect, process and share data between local, state, and federal agencies to increase efficiency and resource allocation

- **Objective 6.3**: Develop opportunities for public-public and public-private partnerships for operations and maintenance.

This study attempts to do a comprehensive cost analysis with available archived data on maintenance activities for selected technologies and locations in COATS region. The case studies will include the following information for each reviewed system: device type and location, date of deployment, description of device's intended purpose, description of device's integration with the ITS network (if any), extent of vendor and contractor support, cost of maintenance activities, cost of operations (if available), and maintenance history.

1.3. Study Benefits

The details included in these case studies will provide information that may help future ITS design and deployment, and also facilitate better budgeting for maintaining ITS devices in rural areas. A comparison of maintenance costs for different ITS systems is facilitated through these case studies. Information from a more comprehensive study of this type can help agencies select the type of communication and power source and other components of a system for future deployment.

The maintenance history documented as part of the case studies will help determine the personnel and skill set requirements for ITS maintenance. The maintenance history can also help agencies allocate the ITS maintenance personnel's schedules as they are often shared among different functions of an agency over a given year. These improvements will result in a better response time in attending to maintenance issues and will lead to better ITS operations and driver satisfaction. A more comprehensive documented maintenance history similar to this study will result in a better estimation of the reliability and lifetime of the system. This will help improve the life-cycle analysis of ITS deployments.

In summary, the device-level detail provided through these case studies should aid in establishing a robust and sustainable regional ITS program.

1.4. Organization of This Document

Chapter 2 provides an overview of the published work in the area of ITS maintenance. Chapter 3 describes the methodology used in this document. As one of the objectives of this study was to determine the costs related to establishing a regional ITS program in order to maintain the ITS deployments in the region, Chapter 4 covers the costs related to establishing a regional ITS program.

Chapter 5 provides the details on each of the individual case studies. The last chapter summarizes this study findings and conclusions. The last chapter also provides a section on future research needed in this area.

2. BACKGROUND

Existing published or documented work on ITS maintenance is very limited. There have not been any studies published on ITS maintenance cost estimates based on historical maintenance cost information. This chapter reviews the existing relevant literature and identifies the unique challenges in maintaining ITS devices located in rural areas.

2.1. Studies on ITS Maintenance

The maintenance strategies followed by agencies deploying ITS typically fall into one of three categories: “Do Nothing”, “Response/Reactive Repair”, and “Program Maintenance” (3). A presentation from 15th ITS America Annual Meeting describes the benefits and dis-benefits of these three strategies. The “Do Nothing” alternative results in high replacement costs and high customer service consequences. This is generally not an option for ITS maintenance. The “Response/Reactive Repair” approach is the typical approach adopted by most of the State DOTs. This approach attempts on solving current problems and does not typically include much failure assessment. This approach has a fragmented replacement process and would likely have inventory issues. The third approach “Program Maintenance” is a systematic asset management approach. It is driven by inspection (i.e. preventive maintenance) rather than malfunctions. This approach helps develop planned repair work and maintain a better condition and operability of the ITS infrastructure. One of the major conclusions of this presentation was that cause/failure analysis of past maintenance activities is critical to future direction of maintenance.

A few metropolitan areas have developed a maintenance plan that outlines generic guidelines to maintain their ITS infrastructure in a systematic way. For example, Minnesota Department of Transportation has developed maintenance plan for ITS in twin cities region. Texas Department of Transportation and Washington Department of Transportation have developed ITS maintenance plan for some of their urban areas. Some of the maintenance plans of the metropolitan areas include preventive maintenance. However, there has not been a statewide ITS maintenance plan until WTI helped Oregon DOT develop a statewide ITS maintenance plan. It developed a schedule for preventive maintenance and a comprehensive budget, and also examined the training and contracting needs for ITS maintenance in Oregon.

There has been growing discussion about ITS maintenance issues. A paper presented at the 14th Annual Meeting of ITS America in 2004 described an experience obtained from over three years of contracting maintenance of ITS deployments in Florida DOT District 6, including both legacy and newer systems. They noted that it was difficult to have a good understanding and estimation of the costs associated with ITS maintenance due to lack of information and experience on ITS maintenance around the country (4). The presentation also stated that a good ITS design should be revised extensively to accommodate maintenance where possible. The other key recommendations of this presentation are as follows:

- Easy access to ITS devices saves money on maintenance
- A preventive maintenance program is a must and will save money.

- Equipment selection of the equipment that meets the technical requirements and has warranties and technical support for the projected lifespan of the equipment

- Protecting the communication infrastructure can be expensive and time-consuming. but is vital to protect the "arteries" of the system

This presentation also indicates that District 6 of Florida DOT has started tracking ITS maintenance activities by implementing inventory controls for all of the parts and equipment along with a system of work orders linked to this inventory. It should be noted that District 6 includes Dade and Monroe Counties and may not be categorized as rural.

Colorado has developed an asset management system for ITS maintenance. This asset management system is part of the five-year program called the Colorado Transportation Management System (CTMS). CTMS provides the State of Colorado a focal point for incident detection, analysis and control of the State's highway infrastructure. CTMS is a five-year program to design, build, operate and maintain the statewide ITS in Colorado. This system tracked ITS maintenance activities through a Microsoft Access® database, and has helped the State to estimate the long-term costs associated with different manufacturers, and different styles of field equipment. For example, the State requires all Dynamic Message Sign (DMS) to be an LED-based sign due to the long-term maintenance costs of the various manufacturers and styles. The other important data obtained through the database include Mean Time Between Failure (MTBF) and Mean Time to Repair (MTTR) for each piece of major equipment and individual components (5).

A summer 2004 article published in ITE's ITS Council Newsletter summed up the contracting experience of Michigan DOT in ITS maintenance. Michigan DOT has moved toward contracting long-term to maintain their ITS devices (6).

The New Mexico DOT formerly known as New Mexico State Highway and Transportation Department (NMSHTD) rebuilt the Big I interchange in Albuquerque and used an ITS-based mobile traffic monitoring/management system during the construction of Big I. The primary lessons learned from this experience of NMSHTD is to consider future maintenance requirements when planning and deploying an ITS (7). The lessons learned published by NMSHTD emphasize that it is important to identify what maintenance needs can be met in-house and to get training from the vendor.

2.2. ITS Maintenance Challenges

ITS is still relatively new for state DOTs and the skill sets required to perform ITS maintenance activities are typically different from the skills required to perform regular highway electrical maintenance activities (e.g. highway lighting and traffic signal maintenance). Maintenance personnel are typically used for multiple functions within state DOTs. This presents a challenge to the State DOTs as they need to recruit personnel for ITS maintenance with a more specialized skill sets beyond those used for recruiting general highway electrical maintenance personnel. Other general maintenance positions that may perform some ITS maintenance activities in the field are Electricians, Telecommunications personnel and Information Systems personnel. It is uncommon to expect one of these three types of personnel (e.g. Electrician) to be able to resolve a problem in the other two components of field elements (i.e. telecommunications and information systems related). This necessitates that the right personnel be identified to be sent to the field to avoid multiple trips to solve one problem.

Most of these challenges are common between urban and rural areas. However, maintaining ITS devices in rural areas has several additional challenges compared to ITS maintenance in urban areas as described below.

1. Attending to ITS devices in rural areas may require longer travel distances.
2. There is a lack of availability of maintenance personnel with specialized training for ITS maintenance in rural areas.
3. Outsourcing rural ITS maintenance to private firms through different types of contracts is more expensive than the same service in urban areas due to long travel times and the fewer number of qualified firms that may compete for the same contract.
4. The maintenance and operations budget for rural ITS has not kept up with the increasing number of ITS devices.
5. Larger geographical areas covered by limited number of ITS devices does not provide any redundancy that could allow for longer individual field element downtime (i.e. non-working time) for most of the ITS devices in rural areas.

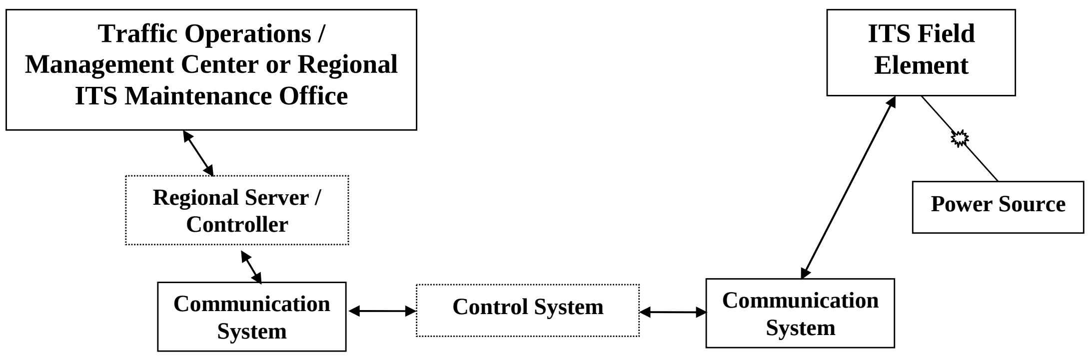
2.3. ITS Maintenance Budgeting

Budgeting for ITS maintenance is critical to the success and sustainability of current and future ITS deployments. The current literature cited in earlier sections of this Chapter has not used empirical data on maintenance costs and activities. It is important to budget adequately for ITS maintenance so that the lifecycle costs of the ITS infrastructure are optimized. The annual total maintenance costs are expected to be higher when there are no preventive maintenance programs in place. A categorization of maintenance costs is provided in Chapter 3. Empirical data on the maintenance activities and expenditures collected from Caltrans and Oregon DOT were used to develop the case studies presented in Chapter 5 and subsequent chapters.

3. METHODOLOGY

The annual cost of maintaining ITS devices varies significantly with their geographical location. Figure 3-1 shows a simplified conceptual diagram of operational components that may be involved in the operation of roadside ITS devices. These components may include the field element (e.g. CCTV), power source (e.g. commercial power), communication system (e.g. telephone line), control system (e.g. programmable logic controllers [PLC]), and Traffic Operations Center / Traffic Management Center / Regional ITS Maintenance Office. Not all ITS devices have all of these components. The frequency of system errors or failures that require a response of maintenance staff may also depend on the type of power source and communication system used, apart from the geographic location of the system.

Figure 3-1: Operational Components of ITS Field Devices



Note: "Control System" and "Regional Server / Controller" may not always be included

It is expected that systems at different locations would have varying annual maintenance costs even if they have similar components for their operation. A case studies approach, where the maintenance histories of individual deployment locations are analyzed, was chosen to capture the varying nature of annual maintenance costs for the following reasons.

- Estimating annual average maintenance costs could be misleading as there is significant variability in annual maintenance costs for the same ITS device type.
- The case studies approach will allow readers to select a case study in this document that is closest to the device and location they are interested in and obtain more accurate information on maintenance than combined average values. It should be noted that the findings presented in these case studies are specific to the site and may not be generally extended to estimate the cost of maintenance for other sites. A more comprehensive study as suggested in the final chapter of this report will develop more generalizable results.

- As annual maintenance costs are expected to vary depending on the communication system and power sources used, this approach could help to capture the varying characteristics of the power and communication options with respect to maintenance.

In describing this project's methodology, this chapter will start by describing how case studies were selected, how maintenance histories were obtained and analyzed, and how costs were classified.

3.1. Selection of Case Studies

There are numerous variables that are expected to significantly influence annual maintenance costs of ITS devices. Therefore, the intent was to select a group of case studies that would cover a good range of typical ITS maintenance scenarios in rural areas.

Caution should be exercised in using the information presented in the case studies in this document. Sites selected for this study were generally chosen because they have had a history of maintenance problems. There may be numerous other sites in the same regions where there have been no maintenance needs since their installation except for any preventive maintenance activities.

3.1.1. Technology Identification

A list of all ITS technologies that have been deployed in at least three locations in the COATS region were identified. The identified technologies included the following:

- CCTV cameras
- road weather information systems (RWIS)
- highway advisory radio (HAR)
- dynamic message signs (DMS) (also known as changeable message signs [CMS] or variable message signs [VMS])
- traffic management center (TMC) / traffic operations center (TOC)
- landslide detectors
- automatic vehicle location (AVL) systems

This list of technologies was presented to the evaluation team for this project and the evaluation team was asked to rank the importance of maintenance information on these technologies. CCTV cameras, RWIS, DMS and HAR were selected as the four most important technologies to be examined.

3.1.2. Site Identification

Caltrans and ODOT ITS maintenance personnel were asked to select sites that would capture a wide range of sites in terms of maintenance experience. Table 3-1 shows the information that was collected with the use of the questionnaire.

Table 3-1: Questionnaire for Initial Data Collection

Information Group	Information
Location Details	MilePost
	Nearest City
Data Availability	Are Maintenance Logs Available?
	available?
	How long (approximate number of years) is the data available for?
Contact Person	Email
	Phone

The sites were identified and tentatively finalized with the help of the information collected using the above questionnaire. Once the sites were finalized, a follow-up questionnaire was sent out to the same Caltrans and ODOT staff. This questionnaire included the questions shown in Table 3-2. The information collected in the follow-up questionnaire was used to further refine the selection of sites to represent a wide range of communication and power options and their influence on annual total maintenance costs.

Table 3-2: Follow-Up Questionnaire on Device Details

Information Group	Information
Communication	Is the device on Field Element Network (FEN)?
	If the device is not on FEN, what type of communication is used?
	How often does the device communicate with the TMC/ Transportation Infrastructure ?
Power	How is the device powered?
	How much power does the device need? (Ex: 20 V, 12 AMP, 50 Watts)
Travel	What is the nearest maintenance yard/ resource for personnel?
	What is the approximate cost of travel for the personnel to reach this field element?
Replacement Costs	Is information available on the costs of replacement parts for the devices?
	If available, where can cost information be found?

A total of 36 case studies were selected; the distribution of these studies across the technologies is shown in Table 3-3.

Table 3-3: Selected Case Studies

System	Number in Oregon	Number in California	Total
CCTV	10	6	16
RWIS	2	3	5
CMS/VMS	4	3	7
HAR	1	2	3
TOC/TMC		2	2
Radar CMS		3	3
		Total	36

More details on the selected representative sites from Caltrans District 2, and ODOT Regions 3 and 4 are shown in Table 3-4 and Table 3-5. These particular devices were selected to capture the variability in annual maintenance costs for the six ITS technologies listed above.

Table 3-4: Selected ITS Field Devices from Caltrans District 2

Technology	Sites	Location
CCTV Cameras		
1	Snowman Hill	SIS-89 PM-29.25
2	Hilt Sandhouse	SIS-5 PM-R68.33
3	Cedar Pass	MOD-299 PM-51.48
4	Mount Hebron	SIS-97 PM-34.46
5	Weed Airport	SIS-5 PM-R25.70
6	Red Bluff	THE-5 PM-R26.52
RWIS		
1	Oregon Mountain Summit	TRI-299 PM-48.00
2	Snowman Hill	SIS-89 PM-29.25
3	Black Butte Summit	SIS-5 PM-14.45
CMS/VMS		
1	5 N/B at Reams Rd.	SIS-5 PM-9.68
2	5 S/B at Walters Road	SIS-5 PM-44.30
3	5 N/B at Smith Road	SHA-5 PM-10.86
HAR		
1	HAR at Hallelujah junction Agricultural Inspection station	LAS-395 PM-1.50
2	HAR at Four Corners	SHA-299 PM-80.20
TOC/TMC		
1	District 2 RTMC	District 02 Office
2	Field Element Network	District 02 Office
Others		
1	Sidehill Viaduct Radar CMS (Combination of CMS, CCTV and Radar speed detection and warning)	SHA-5 PM-29.90
2	Lamoine Radar CMS (Combination of CMS, CCTV and Radar speed detection and warning)	SHA-5 PM-49.10
3	Sims Radar CMS (Combination of CMS, CCTV and Radar speed detection and warning)	SHA-5 PM-57.40

Table 3-5: Selected ITS Field Devices from ODOT Regions 3 and 4

Technology	Sites	Location
CCTV Cameras		
1	Paisley	Ore 31 MP 98
2	Quartz Mountain	ORE 140 MP 68
3	Warner Mountain	ORE 140 MP 4
4	Lake of the Woods	ORE 140 MP 36
5	Siskiyou Pass	I-5 MP 4.5
6	Siskiyou Pass - Exit 6	I-5 MP 5
7	Wards Butte	I -5 MP 168
8	Port Orford	US 101 MP301.58
9	Bend Mountaintop Camera 1	
10	Bend Mountaintop Camera 2	
RWIS		
1	Willamette Pass	Hwy 58 MP 62
2	Siskyou Summit	I-5 MP 4.5
CMS/VMS		
1	Hilt Portable VMS	I-5 Hilt, CA
2	Bailey Hill Portable VMS	Bailey Hill I-5 MP2
3	Medford	ORE 140 MP 13.8
4	Klamath Falls	ORE 140 MP 63
HAR		
1	Ashland HAR	I-5 SB MP 16

Note: Some of these sites were not included in the detailed case studies for lack of available data

3.2. ITS Maintenance Records

This section delineates the different sets of information that were investigated and collected regarding ITS maintenance activities for the selected devices. Available information that is recorded on different maintenance activities was limited.

3.2.1. Maintenance History and Downtime

Because maintenance needs will vary significantly with factors such as the device technology and location, it was decided to capture the maintenance history of the ITS devices so that it could be used to determine future staffing and budgeting needs. The annual maintenance costs depend on how many maintenance activities (i.e. frequency of occurrence of problems) are performed to keep an ITS device operational in a year. The frequency of maintenance activity is also expected to be dependent on the type of communication and power sources used as many of the maintenance problems are found to be related to communication and power. Therefore, this study focused on capturing the frequency of various maintenance activities for each of the sites in the case study.

When a device is reported to be not functional (i.e. down), maintenance personnel often cannot attend to the problem immediately due to previously reported problems with other ITS devices or other job responsibilities. Therefore, it is expected that the device would continue to be out of service for a certain time period. Downtime is defined as the time difference between when a problem was identified and when the ITS device is fully restored and operational. For the purposes of this study, the downtimes have been categorized to be primary downtime and preventive maintenance delay. Primary downtime is defined as the downtime for the reported problems and the preventive maintenance delay is defined as the downtime for preventive maintenance activities (i.e. the time interval between a preventive maintenance activity is scheduled and it is performed). The downtimes may depend on the distance of the system from the nearest maintenance yard and also the type of communication and power sources used. This study attempts to record system downtimes for the sites included in this study.

3.2.2. Classification of Maintenance Costs

There are three types of costs that may be involved in supporting ITS maintenance: maintenance program costs, preventive maintenance, and repair maintenance. This section discusses how each of these costs is analyzed in this research effort.

<u>Maintenance Program Cost</u>

As indicated earlier, maintenance of ITS devices requires more specialized skills than regular electrical maintenance activities such as repairing highway lighting systems. (A desired skill set for ITS maintenance personnel is included in Chapter 4.) A significant number of ITS devices in a region and the need for this specialized skill set require transportation agencies to adapt by either training existing staff so they can perform ITS maintenance, or hiring a new set of personnel exclusively for ITS operations and maintenance. It should be noted that there is a cost to establishing this ITS operations and maintenance program, regardless of whether it is an existing division or a set of new staff.

Establishing an ITS operations and maintenance program in any region also has a cost attached to it in terms of dedicated personnel to monitor the ITS operations and maintenance and in some cases acquisition of specialized testing equipment. This cost can be considered a base or fixed cost as it may not vary with respect to the volume of maintenance problems. However, this cost may depend on the number of ITS devices in the region as it can be expected that more personnel would be required to ensure continued quality operations as ITS deployment expands.

This study focuses on capturing the incremental costs of preventive and reported maintenance activities. These are costs of attending to reported maintenance problems and also performing preventive maintenance activities. These incremental costs (i.e. costs per activity) may be used to assess the annual maintenance costs by multiplying an estimated number of maintenance activities per year.

<u>Preventive Maintenance and Reported Maintenance Activities</u>

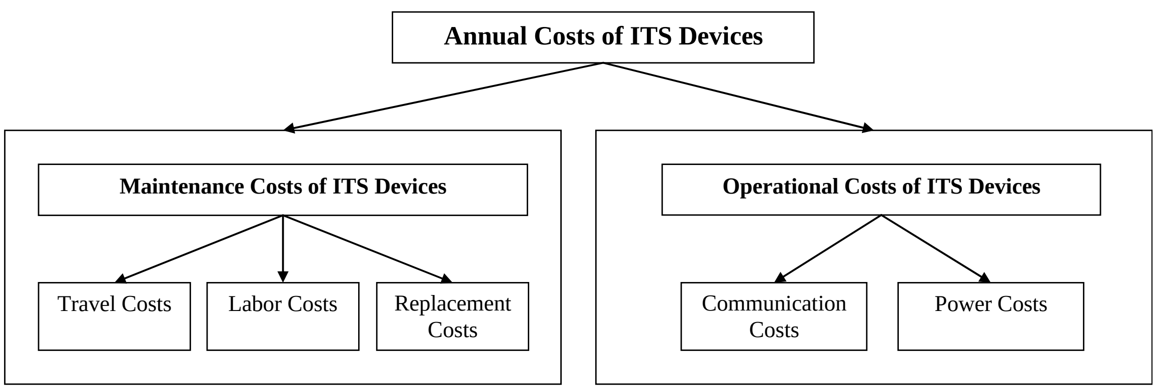
Preventive maintenance includes only the maintenance activities performed by maintenance staff on a scheduled basis even though there may not be a reported problem with the system. Preventive maintenance activities may be performed at regular or non-regular intervals. One form of regular preventive maintenance that the Caltrans District 2 ITS personnel conduct is examining the video feed or camera images from their highway CCTV cameras twice a day for verification during weekdays.

Reported maintenance activities include all of the maintenance activities other than preventive maintenance. These may include activities such as remote diagnostic testing at regular intervals to assure proper operations of ITS devices.

Maintenance Cost Components

The annual costs of ITS devices have several components as shown in Figure 3-2. This study focuses on the maintenance costs on the left side of Figure 3-2. The operational costs shown on the right side of Figure 3-2 are provided in this study whenever the data was available.

Figure 3-2: Components of Maintenance Costs



Travel costs depend on the distance of the location of ITS devices from the nearest ITS maintenance shop. The labor cost component includes the travel time for personnel between the maintenance yard and the device. Replacement costs are costs of components that need to be replaced (e.g. cost of telephone cable replaced).

Priorities and Performance Standards for ITS Field Elements

It should be noted that the priorities for repairing different ITS field elements vary and these priorities also differ between California and Oregon. In other words, some types of elements are a higher priority than others. The priorities influence the downtimes of these ITS field elements. This study does not account for the difference in priorities of various ITS field elements between the two states (i.e. California and Oregon). The performance standards to which these ITS field elements are maintained influence the annual maintenance costs and the downtimes and the performance standards vary for different ITS field elements and across jurisdictions. This variance in performance standards is outside of the scope of this study.

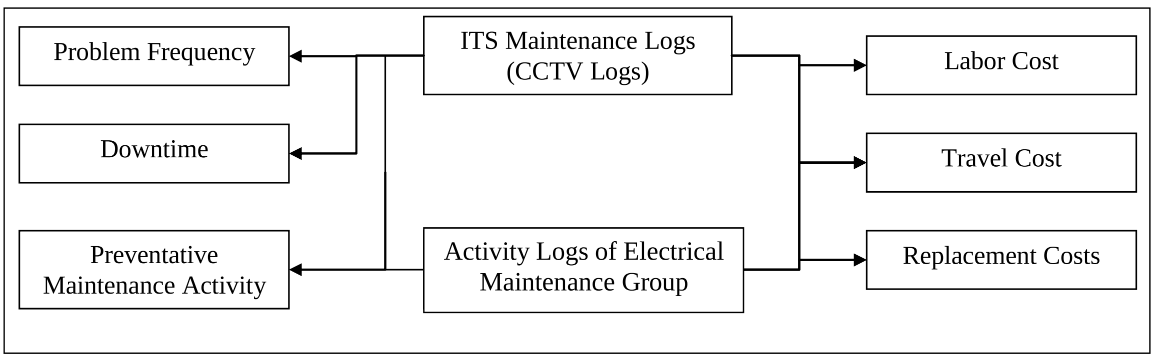
3.3. Data Collection and Synthesis

Once the sites for case studies were finalized, a request for all available information on maintenance of the selected sites was sent out. The following subsections describe the data collected from Caltrans District 2 and ODOT Regions 3 and 4.

3.3.1. California

The case studies included in this project were from Caltrans District 2. ITS devices in Caltrans District 2 are being maintained by two groups: the ITS Engineering and Support group and the Electrical Maintenance group. These two groups keep their own records of activities, and they are not integrated. Figure 3-3 shows the interaction between these two sources of information (i.e. documentation) and the synthesized ITS maintenance activity and cost information.

Figure 3-3: California Maintenance Activity and Cost Data Synthesis



An ITS maintenance log for CCTV and FEN communications network related activities (CCTV log) is created when there is a reported problem and is closed when the problem has been resolved by the ITS Engineering and Support Logs. The information included in this log is shown in Table 3-6. The log forms also have space for comments and other information to be recorded.

Table 3-6: Information in ITS Maintenance Logs (CCTV Logs)

Information Group	Information
General Information	Ticket Number
	Problem reported by
	Site location
	FEN
	TMC/BER
	Date opened
	Time opened
Repair Information	Ticket closed by
	Total man hours
	Date closed
	Time closed

A check mark on the FEN (i.e. Field Element Network) entry means that the specific activity for which the log was opened relates either to regular monitoring of the network or a problem identified during the regular monitoring. A check mark on the TMC / BER (i.e. Traffic Management Center) entry means that the specific activity of the log relates to a reported problem in the TMC. A check mark and name on the CCTV site location entry means that the specific activity of the log relates to a reported problem at that site.

The Electrical Maintenance group's activity logs include the information shown in Table 3-7.

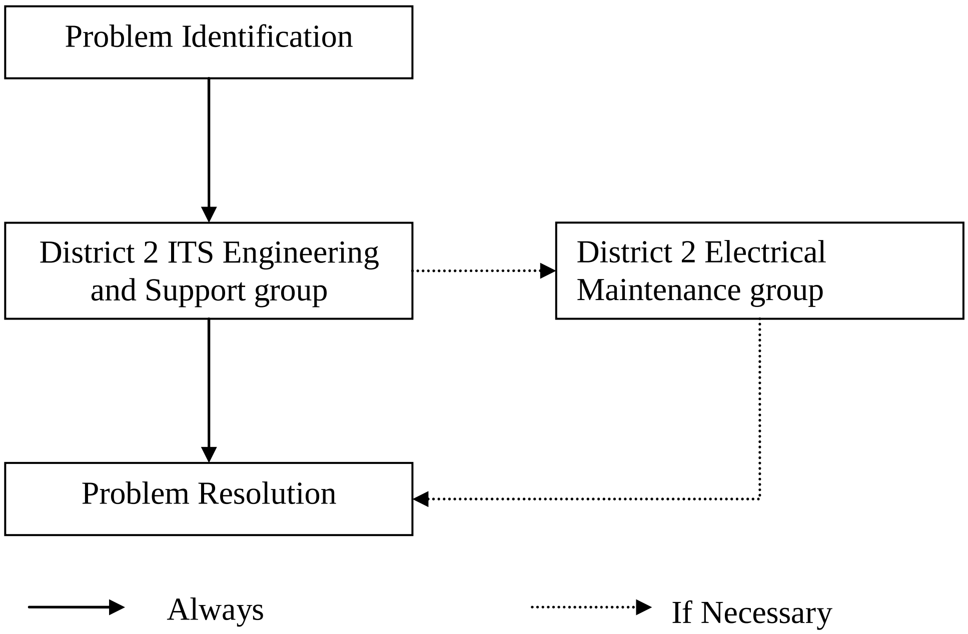
Table 3-7: Information in Activity Logs from Electrical Maintenance Group

Information Group	Information
Activity Details	Work Order Number
	Activity Type
	Asset Type
	Unit ID
	Date Initiated
	Date Completed
Cost Details	Charge Date
	Charge Type
	Item Number
	Item Description
	Quantity / Usage
	Cost per Item

Activity Type indicates whether the activity was preventive maintenance or a reported maintenance activity. Charge Type indicated whether the cost charged is labor or vehicle usage costs. The activity logs from the Electrical Maintenance group have the costs associated with the referred maintenance activities.

Some of the maintenance problems identified were resolved by the District 2 ITS Engineering and Support personnel, whereas other maintenance problems were referred to the Electrical Maintenance group as shown in Figure 3-4.

Figure 3-4: Typical ITS Maintenance in Caltrans District 2



Data from the two sources of information was obtained for the time periods between November 2002 and July 2003 initially. Additional data for the time period between August 2003 and June 2004 was also obtained in the form of CCTV logs.

The two data sources were combined to identify the annual costs of maintenance of the devices included in the case study.

3.3.2. Oregon

There were also two sources of information on ITS maintenance in Oregon. When problems with any of the ITS devices are identified, the Regional ITS Coordinator tries to resolve the problem and personnel from the maintenance yard closest to the device may be used to resolve the problem. The Regional ITS Coordinator keeps a record of the maintenance activity, if time permits. These activity logs typically include the date, time and a short description of the problem and the activity in response.

Cost information on the maintenance of ITS devices was available only in the form of biennial budget reports in Oregon. The biennial budget reports include information shown in Table 3-8. This information was used to determine the total annual expenses of maintaining the ITS devices included in the case studies[1].

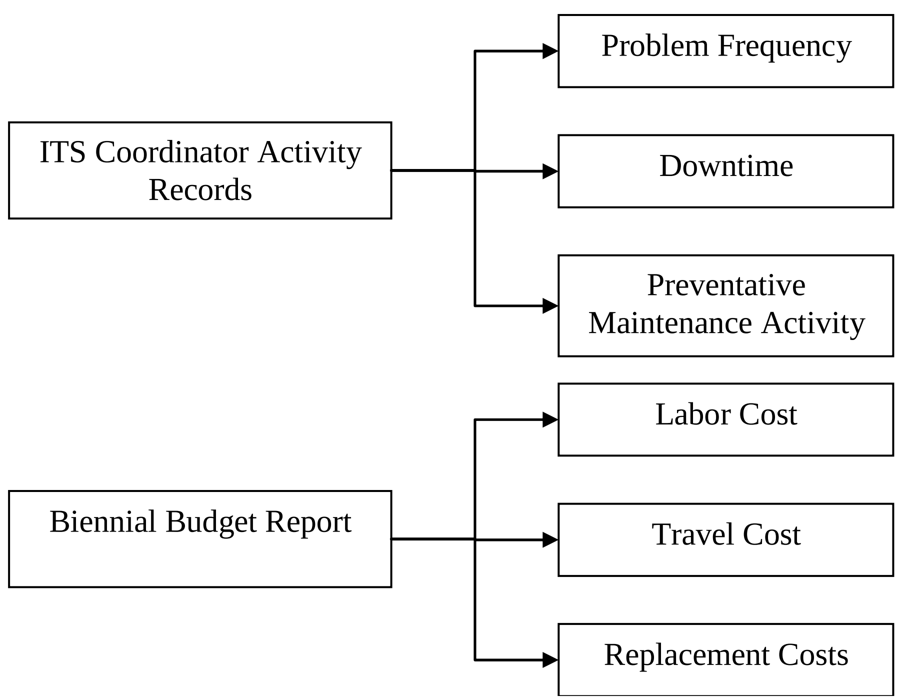
[1] It should be noted that ODOT is looking to implement an activity logging system starting soon.

Table 3-8: Information from Biennial Budget Reports

Information Group	Information
Activity Types	Personnel Services
	Electrical Crew
	Field Operations
	Other
	Service and Supplies
Cost Information	Biennial Budget
	Biennial Expenses
	Encumbarances
	Last Month Expenses

Figure 3-5 shows how the ITS maintenance cost and activity information were synthesized from the two sources of information from Oregon. It should be noted that the ITS Coordinator's activity records are not comprehensive documentations of ITS maintenance for the region. Therefore, the synthesized information from the ITS Coordinator activity records do not necessarily capture all of the maintenance activities. This synthesized information for Oregon would still be a representative sample of maintenance activities and is not expected to be comprehensive, whereas the synthesized information for California is comprehensive.

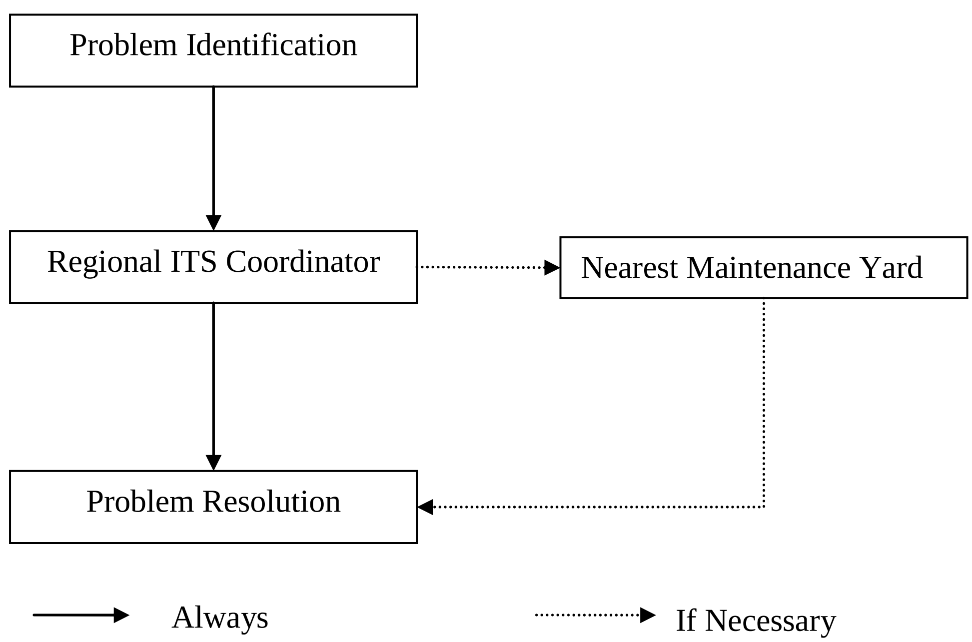
Figure 3-5: Oregon ITS Maintenance Activity and Cost Data Synthesis



Two sets of biennial budget reports were obtained for the selected ITS devices: the time period of fiscal years 2002 and 2003 (i.e. between July 2001 and June 2003), and the time period between June 2003 and September 2003, when the data was obtained. A subsequent set of aggregate data was collected for the time period between October 2003 and December 2004.

Regional ITS Coordinator records included activities for the time periods between January 2000 and July 2004. As indicated earlier, these records are not expected to include all of the ITS maintenance activities for these devices in the time period.

Figure 3-6: Typical ITS Maintenance Activity in Oregon



3.4. Data Synthesis

Most of the data collected as described above was originally in non-electronic format. Therefore, the data was then entered into Microsoft Excel® files. Figure 3-3 and Figure 3-5 show how the maintenance costs and activity frequency were synthesized for California and Oregon, respectively.

The costs of ITS maintenance and frequency of maintenance problems varies enormously depending on the system locations, technology type and the vendor of the system. As indicated earlier, the information presented here in the case studies is synthesized from different sets of information described in Chapter 2 or previous sections of this chapter.

3.4.1. Closed Circuit Television (CCTV) Cameras

Caltrans

The maintenance activities are of two general classifications: preventive maintenance and response to reported problems. Tickets are not mutually exclusive to preventive or non-preventive, although problems are either preventive or non-preventive. Caltrans personnel in

Redding regularly monitor the CCTV cameras in District 2; this monitoring procedure is called the FEN check. Most of the maintenance issues with these cameras are detected during these regular checks. Some of the identified or reported problems may be referenced by a subsequent ticket. This may be because the person who identified a problem has reported and/or assigned it to another person who then opens a new ticket. The maintenance personnel activity was classified into preventive maintenance activity if the CCTV log included the word “FEN” or language similar to “morning check”.

FEN Checks (Preventive Maintenance)

FEN checks are performed at regular intervals irrespective of reported problems. It appears from the CCTV logs that one of the maintenance personnel performed a check on the operations of all of District 2’s cameras once at about 8 AM and again at around 1 PM. It was observed from the CCTV log sheets that one FEN check generally took one person-hour to complete. The FEN checks are classified as preventive in nature because the check includes checking the communication and simple remote troubleshooting if necessary. There are a total of thirty-nine CCTV cameras in Caltrans District 2 that the FEN check covers. Every time a FEN check is performed, there are costs (i.e. labor and communication costs) incurred. This labor time was split equally among the thirty-nine cameras in District 2. This was because a new CCTV log sheet was opened whenever a problem was identified and the labor time was captured in the new log sheet (i.e. ticket). FEN checks are the only form of preventive maintenance performed by Caltrans District 2 ITS Engineering and Support group staff for the CCTV cameras.

Reported Problems

Reported problems are problems with ITS field devices that are reported by some entity other than the ITS program personnel or problems that were not identified during the FEN checks. The tickets related to reported problems were identified with the use of the "CCTV Site Location" field or the description of the activity in the log sheets. It should be noted that traveling to the device location is needed only for some of the reported problems. A travel cost is assigned to the maintenance activity only when a site visit is indicated in the CCTV log sheet. The general observation suggests that most of these maintenance activities related to reported problems had labor times of more than one hour. A common exception to this observation is activity related to a power outage. If the description of the activity section of the tickets refers to another ticket, the two tickets are classified into “linked” tickets. These “linked” tickets were further analyzed to capture the total costs related to the reported problem.

Maintenance Costs Analysis

The tickets were also categorized by individual ITS device and site. The six sites from California are Snowman Pass, Hilt, Cedar Pass, Mt. Hebron, Weed Airport, and Red Bluff. Tickets that were not related to these six sites were not included in the study.

The identified tickets related to each site were then analyzed to estimate the downtime, labor cost and travel cost with the use of estimated travel times to the sites. The following simplifying assumptions were made to perform this analysis.

1. Unless specified otherwise, the time indicated in the CCTV log sheet that indicates the identification of a problem is the start time of an identified problem.

2. Unless specified otherwise, the time indicated in the CCTV log sheet that indicates the closure of a problem is the end time of the problem.

3. If there are multiple tickets that were identified as part of one problem, then the end time of the problem is the time indicated in the latest CCTV log sheet among the multiple "linked" tickets.

As indicated earlier, the CCTV logs only have the hours of labor and not any cost figures. Labor rates varying from $46 to $57 per hour were obtained from Caltrans District 2[2]. The CCTV logs identify which staff person performed the particular maintenance activity. The hours of labor were multiplied by the corresponding rates for the personnel to estimate the maintenance costs. The labor costs are shown in Table 3-9.

Table 3-9: Labor Rates for Caltrans District 2 ITS Personnel

Personnel ID	Salary Rate
1	$46
2	$57
3	$52
4	$52

Calculating Labor and Travel Costs from CCTV Logs

<u>Preventive Maintenance</u>

$$C_P = LC_P = \frac{\sum_{day} LT_{FENi} \times SR_i}{18}$$

where LC_P = preventive labor costs per day for a given location ($)
TC_P = preventive travel costs per day for a given location (0 for FEN checks) ($)
LT_{FENi} = labor time for FEN checks for the day by person i (hours)
SR_i = salary rate for person i ($ / hour)

The preventive maintenance labor costs are generally the same for all the days. The total preventive maintenance labor costs may be obtained by multiplying the cost per day shown above by the number of days in the time period. As mentioned earlier, the only form of preventive maintenance performed by the ITS Engineering and Support group in Caltrans

[2] The CCTV log sheets had the staff person's name on them, and the rates for each staff person were obtained. This information is concealed here for anonymity.

District 2 is the FEN check which does not involve any traveling as it is done remotely from the District Office.

Travel Costs for Reported Problems

Some of the reported problems may involve ITS maintenance personnel traveling to the device location to perform a maintenance activity. Travel costs include the operating costs of the vehicle used to get to the device location, and the labor costs of maintenance personnel for the driving time to and from the device location.

Travel Cost per Problem (TC_R) = Driver Cost (TC_{RD}) + Vehicle Cost (TC_{RV})

Both of the above components are dependent on the distance of the location of the field device from the maintenance office. The average travel time between the maintenance office and the six CCTV camera locations included in this study were obtained from Caltrans District 2. These average travel times are shown in Table 3-10.

Table 3-10: Average Travel Times between Maintenance Office and Site Locations

Site	Travel Time per Visit
Snowman Hill	3 hours
Hilt	5 hours
Cedar Pass	7 hours
Mount Hebron	5 hours
Weed Airport	3 hours
Red Bluff	1.5 hours

If the ticket indicates a site visit, vehicle cost per reported problem (TC_{RV}) was estimated by multiplying average vehicle cost per hour for the type of vehicle used by the average travel time to the corresponding device location. Driver cost per reported problem (TC_{RD}) is estimated by multiplying the salary rate of the driver by the average travel time to the corresponding device location.

$$TC_R = TT_i \times (SR_i + VR_i)$$

where TT_i = average travel time to the device location from the maintenance office (hours) (0 if ticket does not indicate travel)

SR_i = salary rate of person *i* ($ / hour)

VR_j = vehicle rate of vehicle type *j* ($ / hour), where $VR_{ITS\ Van}$ = $14.36 and $VR_{bucket\ truck}$ = $54.00

Table 3-11: Average Vehicle Rates for Different Types of Vehicles

Type of Vehicle	Vehicle Rate per Day
ITS Van	$14.36
45 foot bucket truck	$54.00

Labor Costs for Maintenance related to Reported Problems

$$LC_R = \sum_{problem} LT_{REPi} \times SR_i - TC_{RD}$$

where LC_R = labor costs related to a specific reported problem for a given location ($)
LT_{REPi} = labor time attending to the specific reported problem by person *i* (hours)
SR_i = salary rate for person *i* ($ / hour)
TC_{RD} = driver cost, if travel is indicated in the corresponding tickets ($)

Driver cost (TC_{RD}) is deducted from the labor costs related to the reported problem as these costs are accounted for in the travel costs portion. When a ticket refers to more than one site, the labor time indicated in that log sheet is divided equally among all the referenced sites in the log sheet. Therefore, LT_{REPi} can be part of the labor time indicated in a ticket.

The following lists all of the assumptions made as part of this analysis.

1. Maintenance activities related to reported problems and preventive maintenance activities are mutually exclusive.

2. Every FEN check involves verifying all of the Caltrans District 2 (i.e. thirty-nine) cameras

3. If multiple locations are listed in a ticket, the labor time recorded in the log sheet was spent equally on all sites.

4. The time listed in the earliest log sheet that refers to one problem is the start time of the problem, unless specified otherwise in any of the related tickets.

5. The time listed in the last log sheet that refers to the one problem is the end time of the reported problem.

6. The problems described in different tickets are different from each other unless they refer to each other in their activity description.

7. In the case that the person that is attending to the reported maintenance is not indicated by the ticket, an average rate of $51.75 per hour was assumed.

Calculating Downtime

Reported problems usually have a time period when the system is not fully functional or operational. The difference between the start time of the problem and the end time of the reported problems is defined to be the downtime. The start and end times of the maintenance problems were determined using the definitions above. The downtime was calculated using the following formula:

$$DT_R = ET_R - ST_R$$

where DT_R = downtime of a reported problem (hrs)
ET_R = end time of the reported problem (time of day)
ST_R = start time of the reported problem (time of day)

Labor and Travel Costs from Electrical Maintenance group (ME) Activity Logs

The CCTV log sheets and the activity logs of the Electrical Maintenance group (ME) were correlated to make sure that the same reported problems were not counted twice from the two different sources. If an ME activity log mentions that a location had a problem on the same date or within a maximum of three days that a reported problem is indicated in the CCTV logs, the ME activity is assigned to the same reported problem in the CCTV logs.

The activity logs from the Electrical Maintenance group classified each of their maintenance activities into preventive maintenance, reported problem/repair, and self-indicated repairs. Reported problem/repair and self-indicated repair are generally related to reported problems as defined in this study. The maintenance activity costs and labor times are recorded in these activity logs. These activity logs also identify all of the personnel who were involved in the specific maintenance activity. Though the total cost for each activity was available, salary rates for the ME group personnel (between $36.91 and $42.63 per hour) and the average driving distances from the ME group shop to the sites were used so that the travel costs could be separated out from the total costs for the activity. Since the ME group is also located in Redding, the same average travel distances shown in Table 3-10 were used for calculating the travel costs here.

Table 3-12: Salary Rates for Caltrans District 2 ME Personnel

Personnel ID	Salary Rate
E1	$42.56/hr
E2	$38.75/hr
E3	$38.75/hr
E4	$36.91/hr
E5	$38.75/hr
E6	$38.76/hr
E7	$37.60/hr
E8	$36.91/hr
E9	$42.63/hr
E10	$38.75/hr

NOTE: The ME activity logs identified specific personnel, and the rates for these personnel indicated were obtained. The names are replaced here by an ID for anonymity.

The vehicles used by the ME group are described differently than the ones used by the ITS Engineering and Support group. The vehicle cost per hour for vehicles used by the ME group is shown in Table 3-13.

Table 3-13: Vehicle Use Costs per Hour for ME Vehicles

Vehicle Type	Rate per Hour
Utility Body	$3.55
Personnel HST 34 ft. Art Telescope	$4.74
Personnel HST 28 ft. UB Elec D	$5.22
Personnel HST 45 ft. with utility body	$9.72

The same methods as described earlier were used for calculating the labor costs, transportation costs and the downtime for each reported problem. Preventive maintenance activities do not have a downtime attached to them as the system is usually fully functional when preventive maintenance activities are performed.

Preventive Maintenance

$$C_P = LC_P + TC_P$$

where C_P = total preventive maintenance activity cost for a given location ($)
LC_P = labor cost portion of the preventive maintenance activity ($)
TC_P = travel cost portion of the preventive maintenance activity ($)

The grouped maintenance activities for a given location were first classified into preventive maintenance and reported problem maintenance. After this grouping, the maintenance activities listed to be preventive were further analyzed to determine whether there was travel involved. If there was travel indicated in the ME activity log, the travel costs were separated out of the total activity costs. The travel costs include vehicle costs and driver costs:

$$TC_P = TC_{PD} + TC_{PV}$$

where TC_P = travel cost portion of the preventive maintenance activity ($)
TC_{PD} = driver costs related to the travel cost Portion ($)
TC_{PV} = vehicle cost related to the travel cost Portion ($)

Vehicle costs were provided as a separate item in the activity log reports. The activity log reports also showed the number of hours that the vehicle was used and the total cost of the vehicle use. So, TC_{PV} was obtained directly from the activity logs. Driver costs were estimated based on the average distance of the device location from the maintenance office and the salary rate of the personnel performing the specific activity.

Travel Costs Related to Reported Problems

Travel costs related to reported problems were calculated in the same way as they were calculated for the preventive maintenance activities.

$$TC_R = TC_{RD} + TC_{RV}$$

where TC_R = travel cost portion of the preventive maintenance activity ($)
TC_{RD} = driver costs related to the travel ($)
TC_{RV} = vehicle cost related to the travel ($)

Labor Costs related to Reported Problems

$$LC_R = \sum_{problem} LC_{Ri} - TC_{RD}$$

where LC_R = labor costs related to a specific reported problem for a given location ($)
LC_{Ri} = labor cost item *i* related to the specific reported problem ($)
TC_{RD} = driver cost, if travel is indicated in the corresponding tickets for the specific reported problem ($)

Driver cost (TC_{RD}) is deducted from the labor costs related to the reported problem as these costs are accounted for in the travel costs portion. When a ticket refers to more than one site, the labor time indicated in that log sheet is divided equally among all the referenced sites in the log sheet. Therefore, LT_{REPi} can be part of the labor time indicated in a ticket.

Calculating Downtime

Downtime was calculated using the following equation:

$$DT_R = ET_R - ST_R$$

Where DT_R = Downtime of a reported problem ($)
ET_R = End time of the reported problem ($)
ST_R = Start time of the reported problem ($)

Oregon DOT

As indicated earlier, the maintenance activity logs of ODOT ITS coordinators are not considered to be comprehensive as there is not a standard practice of recording activity details. ODOT is looking to implement a full-fledged asset management system starting in January 2006 for their ITS devices. Data from hard copies of the activity logs were entered into spreadsheets. The information in Table 3-14 was extracted from the activity logs.

Table 3-14: Data from ODOT Activity Logs

Vehicle Type	Rate per Hour
Utility Body	$3.55
Personnel HST 34 ft. Art Telescope	$4.74
Personnel HST 28 ft. UB Elec D	$5.22
Personnel HST 45 ft. with utility body	$9.72

The bi-annual budget reports from ODOT had aggregated costs for the time period between July 2001 and June 2003. This aggregated cost information included an item description. The item description was used to identify whether the costs were associated with labor, transportation, replacement, operations or administration. The table shown in Appendix B was used for this purpose.

3.4.2. RWIS, HAR, CMS/VMS and Other Technologies

Caltrans

The chosen technologies other than CCTV sites did not have regular logs of maintenance activities. Therefore, the ME activity logs were the only source of information for determining problem frequency, downtime, preventive maintenance activities, labor cost, transportation cost and replacement costs when available. The same methodology described above for synthesizing information from ME activity logs was used for the other chosen technologies.

Oregon DOT

The data collected for all of the chosen case studies was similar (i.e. bi-annual budget reports and activity logs), so the same methodology described above for ODOT's CCTV data analysis was used for the other technologies.

3.5. Summary of Overall Methodology

As described above, maintenance logs and budget reports for ITS field elements were obtained from Caltrans and Oregon DOT. The maintenance logs and the budget reports contain two different sets of information on the same ITS elements. These two sets of data were integrated to find the cost of attending to one reported problem or scheduled preventive maintenance. For the purpose of this study, the maintenance activities were segregated into reported maintenance problems (i.e. reported problems or repair maintenance) and scheduled preventive maintenance (i.e. preventive maintenance). Reported problems are maintenance issues and problems as reported or discovered during regular checks and scheduled preventive maintenance activities.

4. ESTABLISHING AN ITS MAINTENANCE PROGRAM

As more and newer ITS devices are deployed, there is a greater need for continuous monitoring of ITS operations and prompt maintenance response to identified problems in ITS operations. Visibly non-functional ITS devices reduce the public's perception of the usefulness of these systems and their confidence in these systems. This necessitates establishing a regional ITS program that will continuously monitor these devices and attend to any problems identified.

4.1. ITS Maintenance Program

The ODOT ITS Maintenance Plan (2) developed by WTI covers the work force requirements for a given level of ITS deployment in a region. ITS maintenance needs a different set of skills than the regular highway related electrical maintenance activities, as indicated earlier. Ian Turnbull, P.E., Caltrans District 2 ITS engineer, was interviewed regarding the skill sets needed for ITS maintenance. The results of this interview and the base cost of establishing ITS programs are also discussed in this Chapter.

4.1.1. Skill Set Requirements for ITS Maintenance

The various categories of skill sets required to maintain ITS devices include video and audio broadcasting, cabling, LAN / WAN, wireless/microwave communications, basic electrical, server administration and security and control systems. More specific skills in these general areas of expertise as suggested by Ian Turnbull, P.E. of Caltrans District 2 are given in Appendix A.

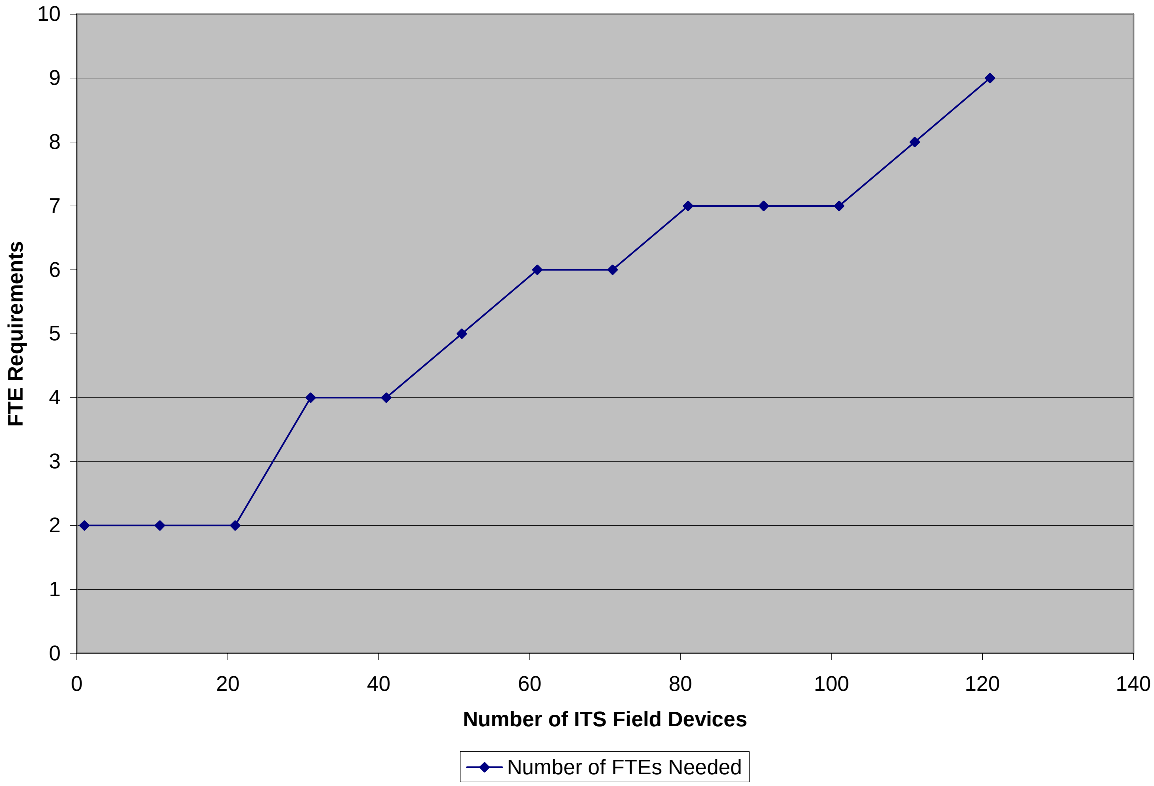
Turnbull interview also suggested that ITS operations and maintenance staff need more skill sets from electronics engineering than traditional electrical engineering. Currently, Caltrans has an Electrical Engineering Technician III position (i.e. personnel with two-year degrees) performing ITS maintenance. It was also mentioned that there are currently not many two-year or four-year degrees that focus on the electronics technician skills and the existing ones have not been updated to include recent changes in networking and embedded computing.

4.1.2. Cost of Establishing a Regional ITS Program

Establishing an ITS program involves employing full-time staff focusing on ITS operations and maintenance, establishing ways to monitor the operation of various ITS field devices and establishing facilities and infrastructure such as a communication network if deemed necessary.

These programmatic costs can be classified into labor costs and infrastructure costs. At least one full-time employee (FTE) is needed to start a regional ITS maintenance program. Though the number of FTEs will vary according to the extent of ITS deployment in the region, the number is not directly proportional to the number of deployed ITS devices. A conceptual diagram representing the relationship between the extent of ITS deployment in a region and FTE requirements is shown in Figure 4-1.

Figure 4-1: Conceptual Diagram of FTE Requirements for Varying ITS Deployment Levels



The infrastructure for establishing a regional ITS program may include one or more of the following:

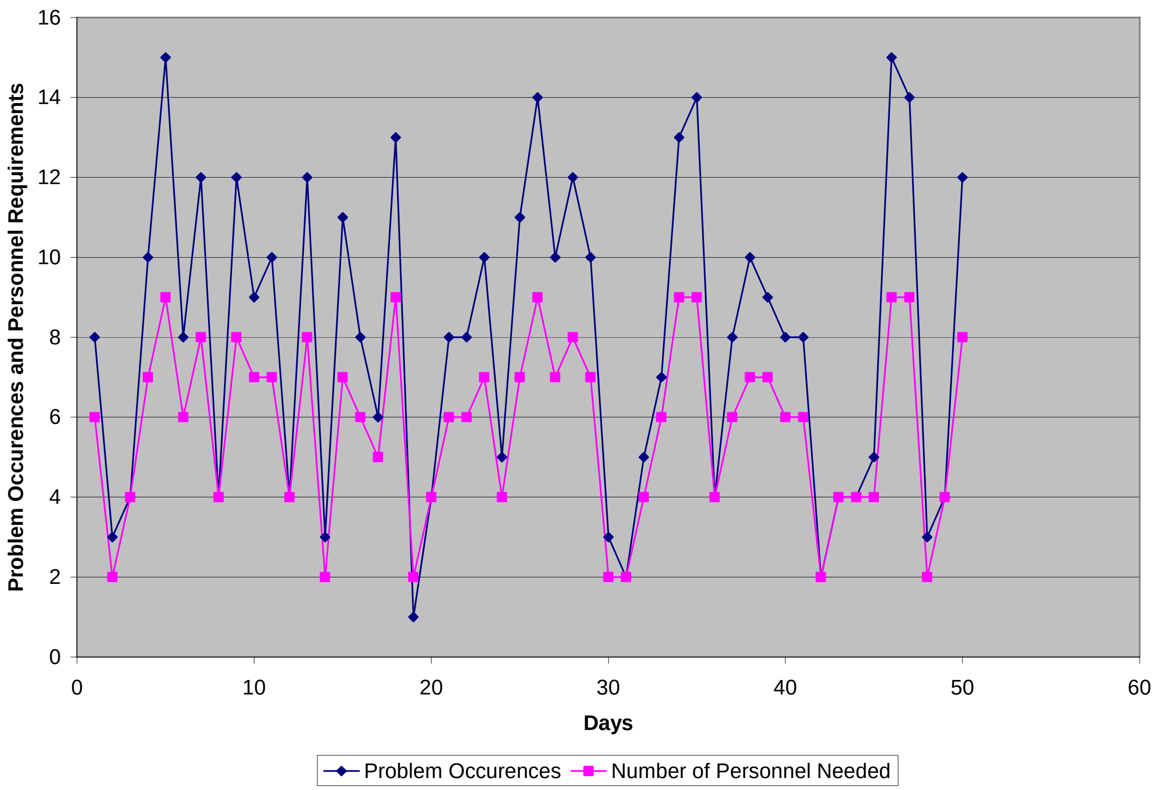
- Centralized ITS operations
- Communication network and associated infrastructure
- Computer servers monitoring and receiving data from ITS field devices
- Self-diagnostic systems

Estimating the costs of the infrastructure for establishing a regional ITS program is beyond the scope of this study; however, a couple of figures may be used to provide a sense of scale. The cost of establishing a centralized ITS operations center could cost millions of dollars. Integrating a remote location CCTV with existing systems or a centralized facility is estimated to be between $2000 and $5000. The operational and maintenance cost for a CCTV located at a remote location is estimated to be between $100 and $250 (8). These are average costs based on available information through data maintained by the ITS Joint Program Office (JPO) of FHWA.

4.1.3. Base and Variable Costs of Maintaining ITS Devices

The FTE requirements for attending to the reported ITS device problems depend on the frequency and time distribution of the occurrence of reported problems in all ITS devices in a region. A conceptual diagram depicting the relationship between the frequency and time distribution of reported problems and the staff requirements is shown in Figure 4-2. This diagram conceptually depicts the FTE requirements for attending to reported problems on the same day.

Figure 4-2: Conceptual Diagram of Occurrence of Reported Problems and Personnel Requirements

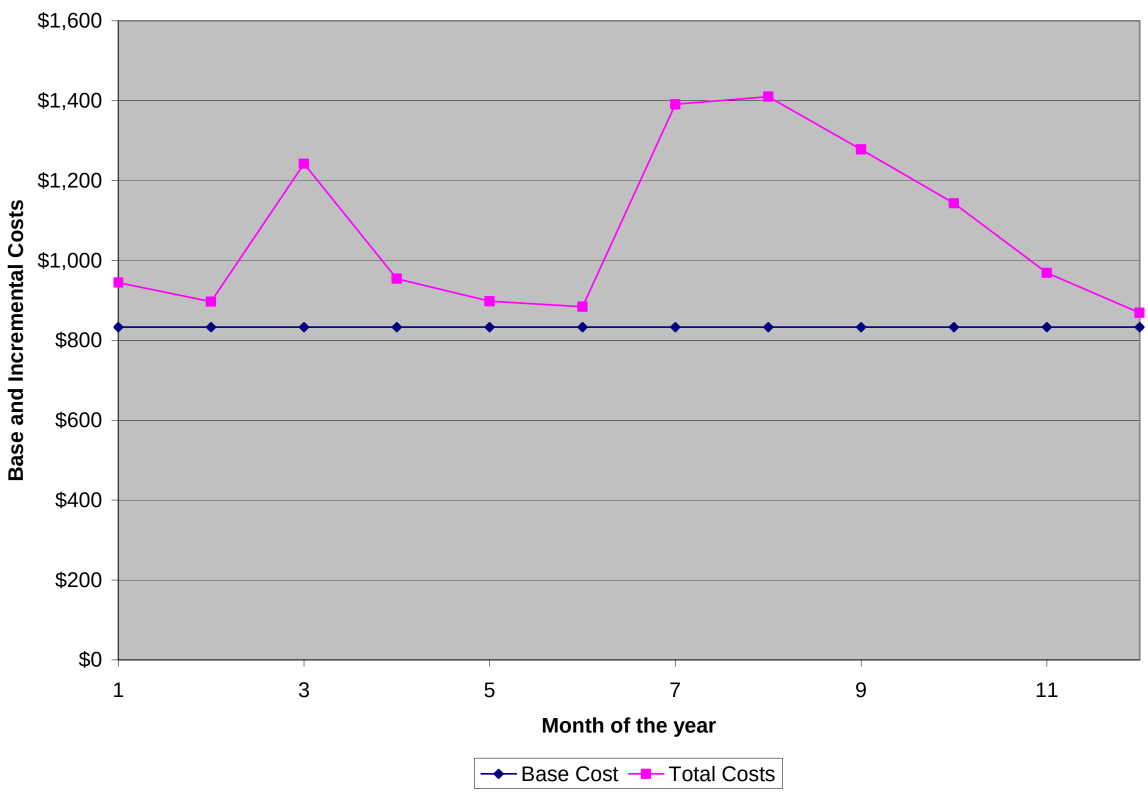


Note: The FTE requirements are based on the reported problems attended on the same day

This study attempts to provide more information on the occurrence and time distribution of reported ITS maintenance issues along with annual estimated of ITS maintenance costs; however, it is a fact that there is not enough information on the occurrence and time distribution of the reported problems to accurately estimate the FTE requirements.

As described above, the recurring annual maintenance costs are directly proportional to the number of reported problems in that year. The number of reported problems is generally expected to increase as the device gets older. However, the actual number of reported problems that occur in the next year is not determinable exactly. This study attempts to capture the incremental costs portion of the annual maintenance costs as shown in Figure 4-3 and also attempts to document the occurrence of reported problems.

Figure 4-3: Conceptual Diagram of Base and Incremental ITS Maintenance Costs



4.2. Summary

Establishing a regional ITS program is necessary for continuous monitoring and operating of ITS field devices as the number of ITS field devices keep growing. The cost of establishing a regional ITS program can be considered a base cost that is fairly constant. The maintenance costs of ITS field devices also have a varying component that is directly proportional to the number of reported problems to which maintenance personnel attend. The annual costs of maintaining ITS devices are also dependent on the time distribution of reported problem. This study attempts to focus on this varying component of ITS maintenance costs through a number of selected case studies.

5. CASE STUDIES

As indicated earlier, the objective of this study was to estimate and document the following information on the maintenance for the chosen device locations.

- Annual maintenance labor costs (preventive, reported problem related)
- Annual maintenance travel costs (preventive, reported problem related)
- Annual average total downtime and average downtime per reported problem (preventive maintenance delay, reported problem related [primary])
- Annual average frequency of problems and their time distribution (preventive, reported problem related)
- Annual power and communication costs (if available)

It should be noted that the power and communication costs are considered operations costs and not maintenance costs. These operations costs are provided when available.

5.1. CCTV Cameras

CCTV cameras are one of the most widely deployed ITS technologies in the nation. Periodic images from these cameras are typically fed into the traveler information web pages that can be accessed by motorists. They are widely used by state DOTs to monitor highway conditions and have been found extremely useful by the highway users when provided through Internet. As indicated earlier in section 3.2.2, Caltrans performs regular checks on their CCTVs twice a day on weekdays. This activity is called Field Element Network (FEN) check. This study also includes Field Element Network (FEN) as one of the case studies. So, these FEN checks have not been included in the analysis of the CCTV case studies to keep them comparable to Oregon CCTVs that do not have scheduled checks similar to FEN checks. The time and costs of these FEN checks are covered in the Rural Traffic Management Center (TMC) at District 2 case study.

For all California camera sites, the CCTV log data on maintenance activities was collected for the time period between November 2002 and June 2004, and ME activity logs were collected for the time period between November 2002 and July 2003.

For the Oregon sites, the time periods for which these activities were available differ for each of the sites; therefore, the annual cost estimates were normalized. Bi-annual budget reports were collected for Fiscal Years 2001-02 and 2002-03 for all of the case studies in Oregon. As indicated earlier, the Regional ITS Coordinator’s activity logs were used to estimate annual averages of problem frequency, downtime and preventive maintenance activities. These activity logs are not necessarily comprehensive.

The primary downtime indicated here is the system downtime for reported problems while the preventive maintenance delay indicates the time period between scheduling a preventive maintenance and the completion of the preventive maintenance.

5.1.1. Snowman Hill, CA

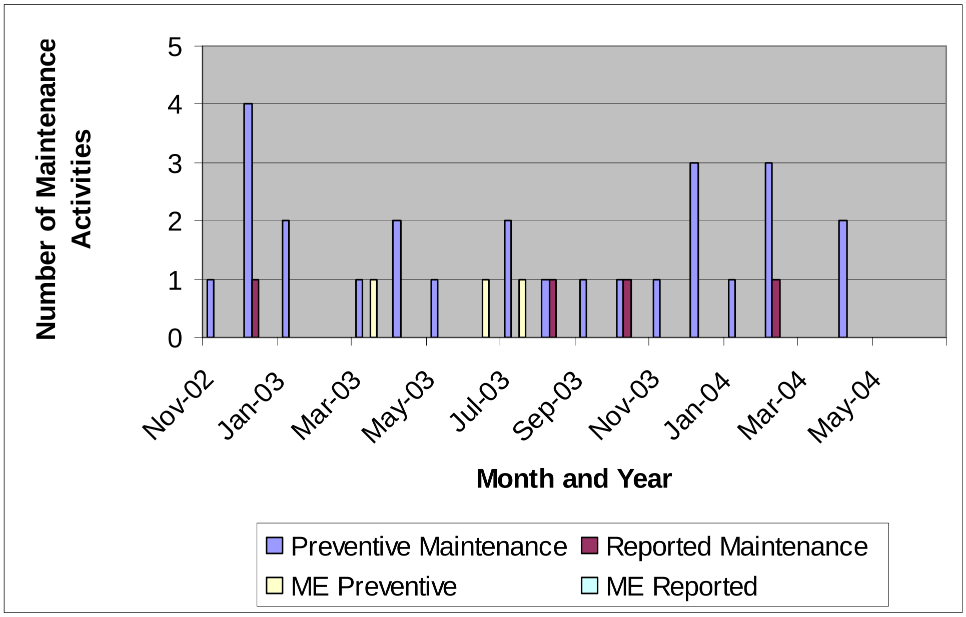
Snowman Hill Cam is located 0.25 miles east of the McCloud Summit, at milepost 29.31, on State Route 89 in California. Table 5-1 shows the number of different types of maintenance activities for the time period of the study. Figure 5-1 shows the distribution of the maintenance activities. Table 5-2 summarizes the annual average costs and downtime estimated from the data for the above time periods.

Table 5-1: Maintenance Activities for Snowman Hill CCTV

Month and Year	Preventive Maintenance	Reported Maintenance	ME Preventive	ME Reported
Nov-02	1			
Dec-02	4	1		
Jan-03	2			
Feb-03	0			
Mar-03	1		1	
Apr-03	2			
May-03	1			
Jun-03	0		1	
Jul-03	2		1	
Aug-03	1	1		
Sep-03	1			
Oct-03	1	1		
Nov-03	1			
Dec-03	3			
Jan-04	1			
Feb-04	3	1		
Mar-04	0			
Apr-04	2			
May-04	0			
Jun-04	0			
Annual Average	**15**	**2**	**2**	**0**

Note: The activities shown here do not include regular FEN checks twice a day for weekdays

Figure 5-1: Maintenance Activity Distribution for Snowman Hill CCTV



Note: The activities shown here do not include regular FEN checks twice a day for weekdays

Table 5-2: Annual Average Costs and Downtime for Snowman Hill CCTV

Site Location	Snowman Hill		
Average Annual Costs	Total Cost		$1,189
	Transportation Cost	Driver Cost	$85
		Vehicle Costs	$117
	Labor Cost		$987
	Replacement Costs		$0
Average Annual Down Time	Primary	Days	19
		Hours	11:06:00
	Preventive Maintenance Delay	Days	4
		Days/Activity	1

5.1.2. Hilt (Sand House), CA

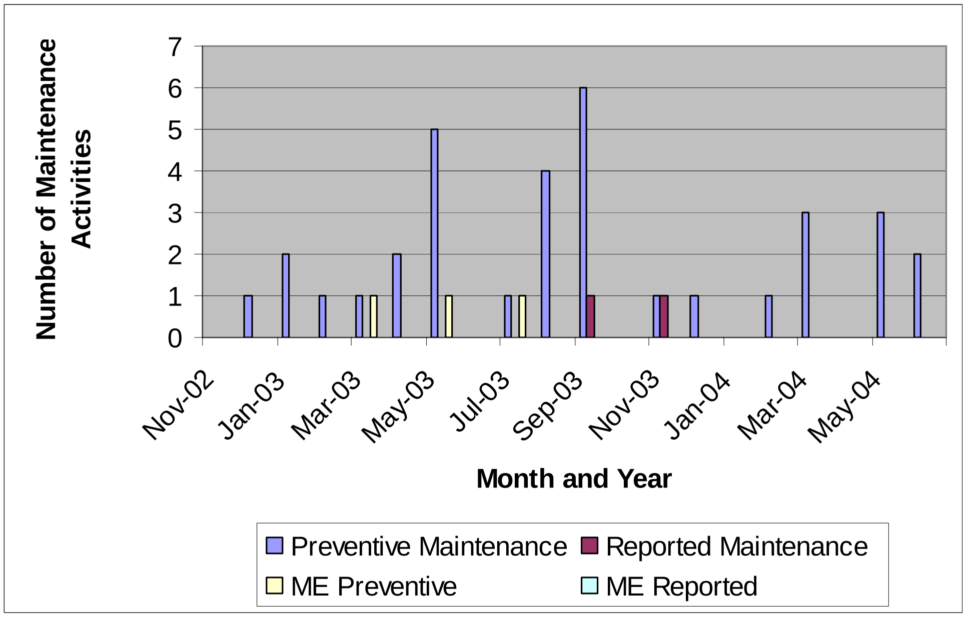
The Hilt camera is located on Interstate 5 at mile post 68.33 in Siskiyou County near the border between California and Oregon. Table 5-3 shows the number of different types of maintenance activities for the study time period. Figure 5-2 shows the distribution of the maintenance activities over the time period. Table 5-4 summarizes the annual average costs and downtime estimated from the data.

Table 5-3: Maintenance Activities for Hilt Sand House CCTV

Month and Year	Preventive Maintenance	Reported Maintenance	ME Preventive	ME Reported
Nov-02	0			
Dec-02	1			
Jan-03	2			
Feb-03	1			
Mar-03	1		1	
Apr-03	2			
May-03	5		1	
Jun-03	0			
Jul-03	1		1	
Aug-03	4			
Sep-03	6	1		
Oct-03	0			
Nov-03	1	1		
Dec-03	1			
Jan-04	0			
Feb-04	1			
Mar-04	3			
Apr-04	0			
May-04	3			
Jun-04	2			
Annual Average	**19**	**1**	**2**	**0**

Note: The activities shown here do not include regular FEN checks twice a day for weekdays

Figure 5-2: Maintenance Activity Distribution for Hilt Sand House CCTV



Note: The activities shown here do not include regular FEN checks twice a day for weekdays

Table 5-4: Summary of Annual Average Costs and Downtime for Hilt Sand House CCTV

Site Location	Hilt		
Average Annual Costs	Total Cost		$541
	Transportation Cost	Driver Cost	$86
		Vehicle Costs	$17
	Labor Cost		$439
	Replacement Costs		$0
Average Annual Down Time	Primary	Days	0
		Hours	15:18:00
	Preventive Maintenance Delay	Days	4
		Days/Activity	1

5.1.3. Cedar Pass, CA

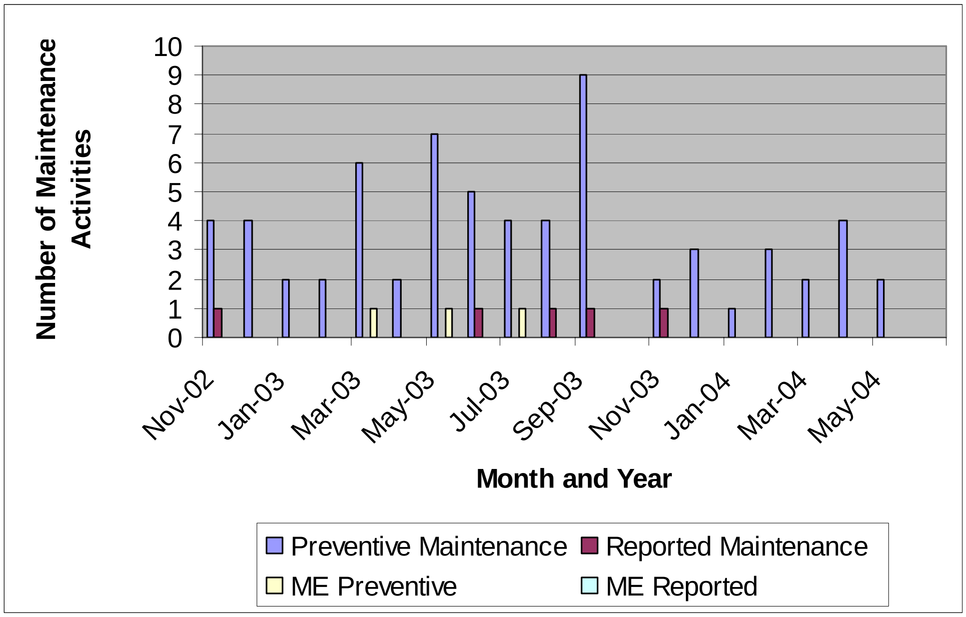
The Cedar Pass camera is east of Alturas, CA. The camera is near the Nevada, California border on Route 299 at post mile 51.48. The camera location is at an elevation of 6034 ft. above sea level. Table 5-5 shows the number of different types of maintenance activities for the time period. Figure 5-3 shows the distribution of the maintenance activities over the above time period. Table 5-6 summarizes the annual average costs and downtime estimated from the data.

Table 5-5: Maintenance Activities for Cedar Pass CCTV

Month and Year	Preventive Maintenance	Reported Maintenance	ME Preventive	ME Reported
Nov-02	4	1		
Dec-02	4			
Jan-03	2			
Feb-03	2			
Mar-03	6		1	
Apr-03	2			
May-03	7		1	
Jun-03	5	1		
Jul-03	4		1	
Aug-03	4	1		
Sep-03	9	1		
Oct-03	0			
Nov-03	2	1		
Dec-03	3			
Jan-04	1			
Feb-04	3			
Mar-04	2			
Apr-04	4			
May-04	2			
Jun-04	0			
Annual Average	**38**	**3**	**2**	**0**

Note: The activities shown here do not include regular FEN checks twice a day for weekdays

Figure 5-3: Maintenance Activity Distribution for Cedar Pass CCTV



Note: The activities shown here do not include regular FEN checks twice a day for weekdays

Table 5-6: Annual Average Costs and Downtime for Cedar Pass CCTV

Site Location	Cedar Pass		
Average Annual Costs	Total Cost		$3,072
	Transportation Cost	Driver Cost	$82
		Vehicle Costs	$784
	Labor Cost		$2,206
	Replacement Costs		$0
Average Annual Down Time	Primary	Days	18
		Hours	14:18:36
	Preventive Maintenance Delay	Days	4
		Days/Activity	1

5.1.4. Mount Hebron, CA

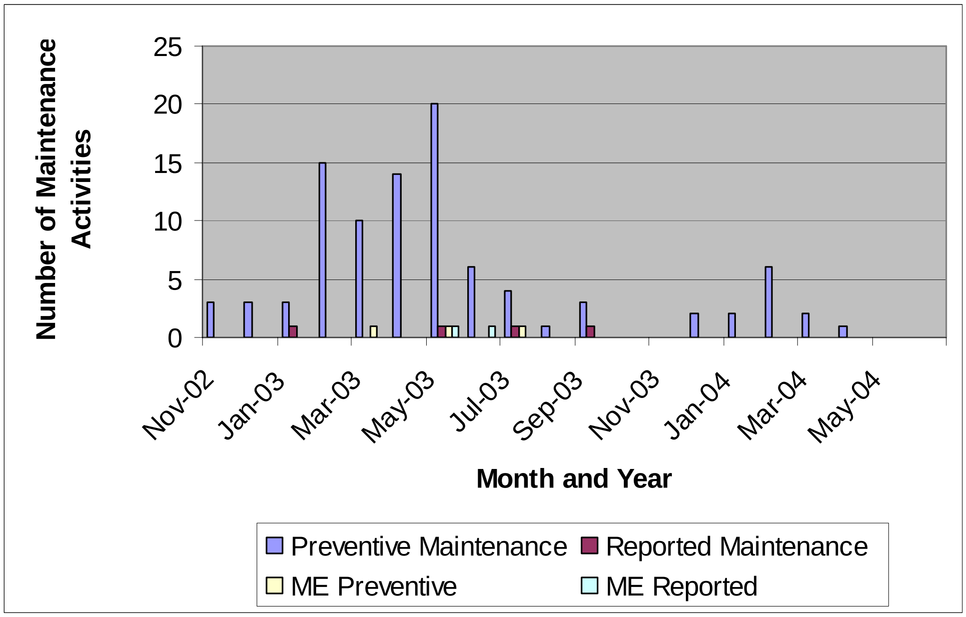
The Mount Hebron camera is located in Siskiyou County near Dorris, CA on route 97, post mile 34.46. The site location is at an elevation of 4301 ft. above sea level. Table 5-7 shows the number of different types of maintenance activities for the above time period. Figure 5-4 shows the distribution of the maintenance activities over the time period. Table 5-8 summarizes the annual average costs and downtime estimated from the data.

Table 5-7: Maintenance Activities for Mount Hebron CCTV

Month and Year	Preventive Maintenance	Reported Maintenance	ME Preventive	ME Reported
Nov-02	3			
Dec-02	3			
Jan-03	3	1		
Feb-03	15			
Mar-03	10		1	
Apr-03	14			
May-03	20	1	1	1
Jun-03	6			1
Jul-03	4	1	1	
Aug-03	1			
Sep-03	3	1		
Oct-03	0			
Nov-03	0			
Dec-03	2			
Jan-04	2			
Feb-04	6			
Mar-04	2			
Apr-04	1			
May-04	0			
Jun-04	0			
Annual Average	**54**	**2**	**2**	**1**

Note: The activities shown here do not include regular FEN checks twice a day for weekdays

Figure 5-4: Maintenance Activity Distribution for Mount Hebron CCTV



Note: The activities shown here do not include regular FEN checks twice a day for weekdays

Table 5-8: Annual Average Costs and Downtime for Mount Hebron CCTV

Site Location	Mt. Hebron		
Average Annual Costs	Total Cost		$4,550
	Transportation Cost	Driver Cost	$286
		Vehicle Costs	$278
	Labor Cost		$3,986
	Replacement Costs		$0
Average Annual Down Time	Primary	Days	79
		Hours	11:18:00
	Preventive Maintenance Delay	Days	7
		Days/Activity	2

5.1.5. Weed Airport, CA

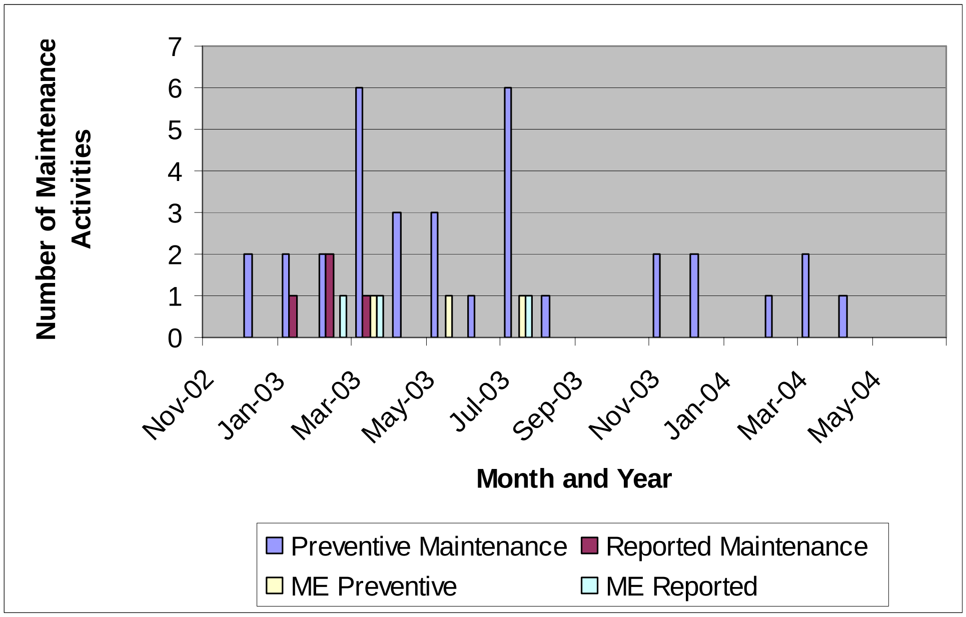
The Weed Airport camera is located in Siskiyou County, near the city of Weed, CA on Route 5, post mile 22.20 at an elevation of 2938 ft above sea level. Table 5-9 shows the number of different types of maintenance activities for the above time period. Figure 5-5 shows the distribution of the maintenance activities over the time period. Table 5-10 summarizes the annual average costs and downtime estimated from the data.

Table 5-9: Maintenance Activities for Weed Airport CCTV

Month and Year	Preventive Maintenance	Reported Maintenance	ME Preventive	ME Reported
Nov-02	0			
Dec-02	2			
Jan-03	2	1		
Feb-03	2	2		1
Mar-03	6	1	1	1
Apr-03	3			
May-03	3		1	
Jun-03	1			
Jul-03	6		1	1
Aug-03	1			
Sep-03	0			
Oct-03	0			
Nov-03	2			
Dec-03	2			
Jan-04	0			
Feb-04	1			
Mar-04	2			
Apr-04	1			
May-04	0			
Jun-04	0			
Annual Average	**19**	**2**	**2**	**2**

Note: The activities shown here do not include regular FEN checks twice a day for weekdays

Figure 5-5: Maintenance Activity Distribution for Weed Airport CCTV



Note: The activities shown here do not include regular FEN checks twice a day for weekdays

Table 5-10: Summary of Annual Average Costs and Downtime for Weed Airport CCTV

Site Location	Weed Airport		
Average Annual Costs	Total Cost		$2,055
	Transportation Cost	Driver Cost	$163
		Vehicle Costs	$106
	Labor Cost		$1,787
	Replacement Costs		$0
Average Annual Down Time	Primary	Days	1
		Hours	15:15:36
	Preventive Maintenance Delay	Days	8
		Days/Activity	1

5.1.6. Red Bluff, CA

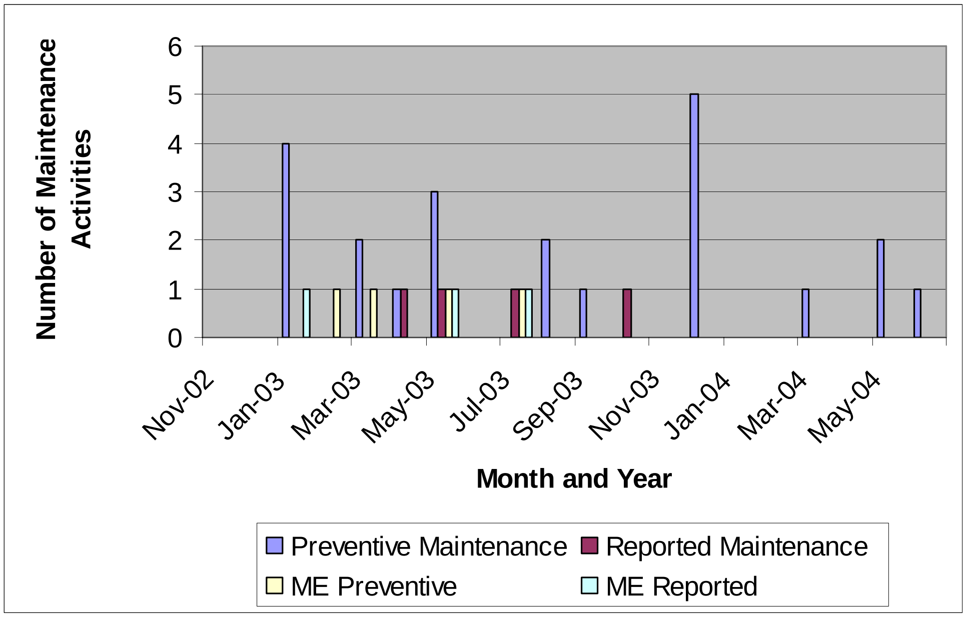
The CCTV camera at Red Bluff is in Tehama County on Interstate 5 at Post Mile R26.52 at an elevation of 335 feet above sea level. Table 5-11 shows the number of different types of maintenance activities for the above time period. Figure 5-6 shows the distribution of the maintenance activities over the above time period. Table 5-12 summarizes the annual average costs and downtime estimated from the data for the above time periods.

Table 5-11: Maintenance Activities for Red Bluff CCTV

Month and Year	Preventive Maintenance	Reported Maintenance	ME Preventive	ME Reported
Nov-02	0			
Dec-02	0			
Jan-03	4			1
Feb-03	0		1	
Mar-03	2		1	
Apr-03	1	1		
May-03	3	1	1	1
Jun-03	0			
Jul-03	0	1	1	1
Aug-03	2			
Sep-03	1			
Oct-03	0	1		
Nov-03	0			
Dec-03	5			
Jan-04	0			
Feb-04	0			
Mar-04	1			
Apr-04	0			
May-04	2			
Jun-04	1			
Annual Average	**13**	**2**	**2**	**2**

Note: The activities shown here do not include regular FEN checks twice a day for weekdays

Figure 5-6: Maintenance Activity Distribution for Red Bluff CCTV



Note: The activities shown here do not include regular FEN checks twice a day for weekdays

Table 5-12: Annual Average Costs and Downtime for Red Bluff CCTV

Site Location	Red Bluff		
Average Annual Costs	Total Cost		$2,009
	Transportation Cost	Driver Cost	$192
		Vehicle Costs	$303
	Labor Cost		$1,514
	Replacement Costs		$0
Average Annual Down Time	Primary	Days	1
		Hours	7:24:00
	Preventive Maintenance Delay	Days	10
		Days/Activity	1

5.1.7. Wards Butte, OR

This CCTV is located on Interstate 5 at milepost 168. As indicated earlier, the activity logs of Regional ITS Coordinator were used to estimate annual averages of problem frequency, downtime and preventive maintenance activities. The Wards Butte CCTV maintenance data was collected for the time period between April 2001 and September 2003. The annual estimates shown here are normalized for the time period variations among different sites. Table 5-13 shows the maintenance activities for this site for the above time period. Table 5-14 contains the estimated annual average downtimes. Figure 5-7 shows the distribution of maintenance activities for this site.

Table 5-13: Maintenance Activities for Wards Butte CCTV

Time Period 1	4/2/2001	9/30/2003
	Preventive	Reported
Apr-01	1	1
May-01		1
Jun-01		
Jul-01		2
Aug-01		
Sep-01		
Oct-01		3
Nov-01		
Dec-01		
Jan-02		
Feb-02		2
May-02		
Feb-03	1	
Apr-03		1
May-03		
Jun-03		2
Sep-03	1	
Annual Average	**1**	**5**

Figure 5-7: Maintenance Activity Distribution for Wards Butte CCTV

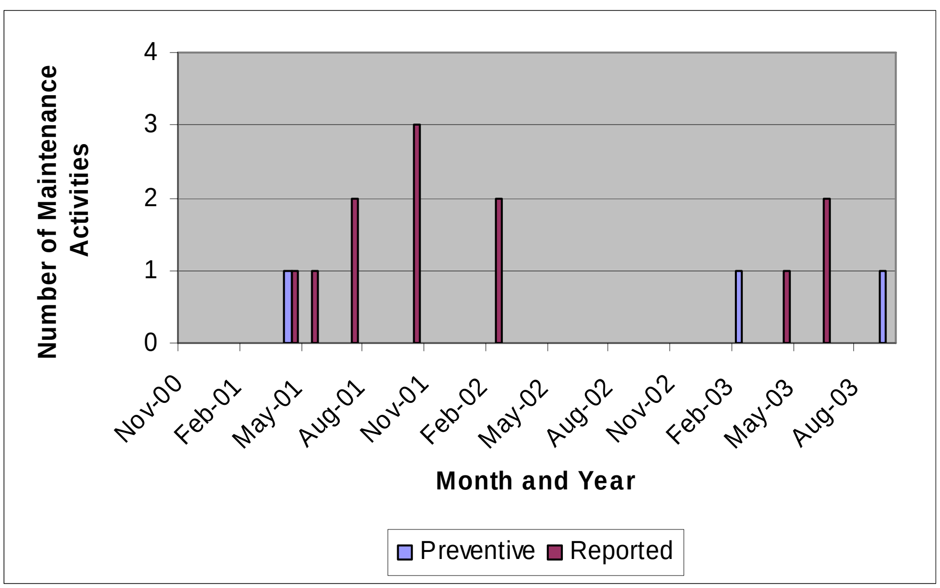


Table 5-14: Annual Average Downtime for Wards Butte CCTV

Annual Average Downtime			
Primary Downtime		Preventive Maintenance Delay	
Days	Days / Problem	Days	Days / Problems
12	2	1	1

Estimated annual average costs of maintenance are presented in Table 5-15.

Table 5-15: Annual Average Costs for Wards Butte CCTV

Site Location	Wards Butte	
Annual Average Costs	Labor Cost	$175
	Transportation Costs	$303
	Replacement Costs	$151
	Operational Costs	$395
	Admin Costs	$22
	Total	$1,045

5.1.8. Port Orford, OR

This CCTV is located on US Route 101 at milepost 301.58 near Port Orford, OR. The Port Orford CCTV maintenance data was collected for the time period between April 2001 and August 2003. The annual estimates shown here are normalized for the time period variations among different sites. Table 5-16 shows the maintenance activities for this site for the above time period. Table 5-17 contains the estimated annual average downtimes. Figure 5-8 shows the distribution of maintenance activities for this site.

Table 5-16: Maintenance Activities for Port Orford CCTV

Time Period 1	4/2/2001	4/10/2003
	Preventive	**Reported**
Nov-00		
Dec-00		
Jan-01		
Feb-01		2
Mar-01		
Apr-01	1	1
May-01		
Jun-01		
Jul-01		
Aug-01		1
Sep-01		
Oct-01		
Nov-01		
Dec-01		1
Jan-02		
Feb-02		1
May-02		
Feb-03		1
Apr-03		
May-03		
Jun-03	1	
Aug-03	1	
Annual Average	**1**	**3**

Figure 5-8: Maintenance Activity Distribution for Port Orford CCTV

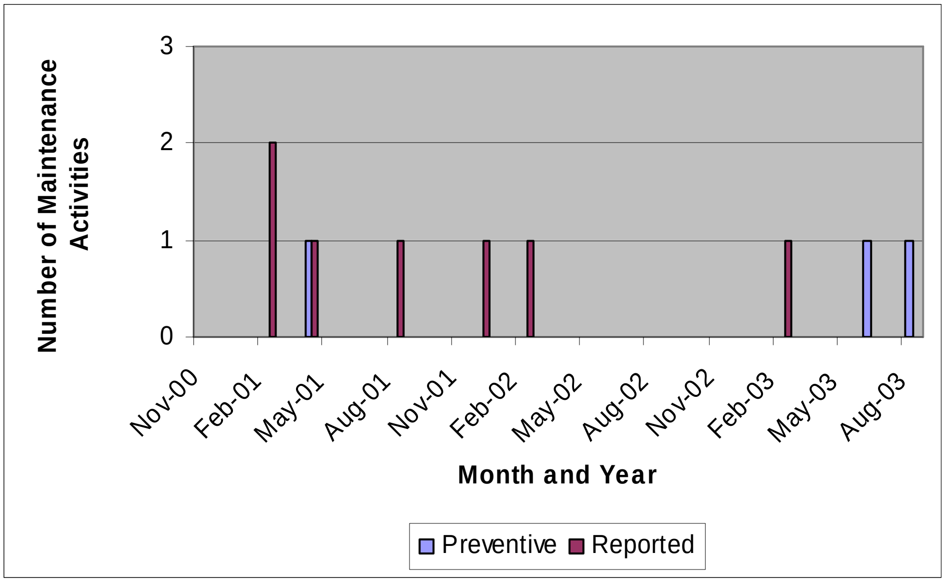


Table 5-17: Annual Average Downtime for Port Orford CCTV

Annual Average Downtime			
Primary Downtime		Preventive Maintenance Delay	
Days	Days / Problem	Days	Days / Problems
8	2	3	3

Estimated annual average costs of maintenance are presented in Table 5-18.

Table 5-18: Annual Average Costs for Port Orford CCTV

Site Location	Port Orford	
Annual Average Costs	Labor Cost	$685
	Transportation Costs	$461
	Replacement Costs	$231
	Operational Costs	$266
	Admin Costs	$0
	Total	$1,643

5.1.9. Siskiyou Summit, OR

This CCTV is located on Interstate 5 at Siskiyou Summit at milepost 4.5. The Siskiyou Summit CCTV maintenance data was collected for the time period between November 2000 and June 2003. Table 5-19 shows the maintenance activities for this site for the above time period. Table

5-20 contains the estimated annual average downtimes. Figure 5-9 shows the distribution of maintenance activities for this site.

Table 5-19: Maintenance Activities for Siskiyou Summit CCTV

Time Period 1	11/13/2000	6/10/2003
	Preventive	**Reported**
Nov-00	1	
Dec-00		
Jan-01		2
Feb-01		1
Mar-01		
Apr-01	1	
May-01	1	
Jun-01		
Jul-01		1
Aug-01		1
Sep-01		
Oct-01		
Nov-01		1
Dec-01		
Jan-02		
Feb-02		
May-02		1
Apr-03		1
May-03	1	
Jun-03		1
Annual Average	**1**	**3**

Figure 5-9: Maintenance Activity Distribution for Siskiyou Summit CCTV

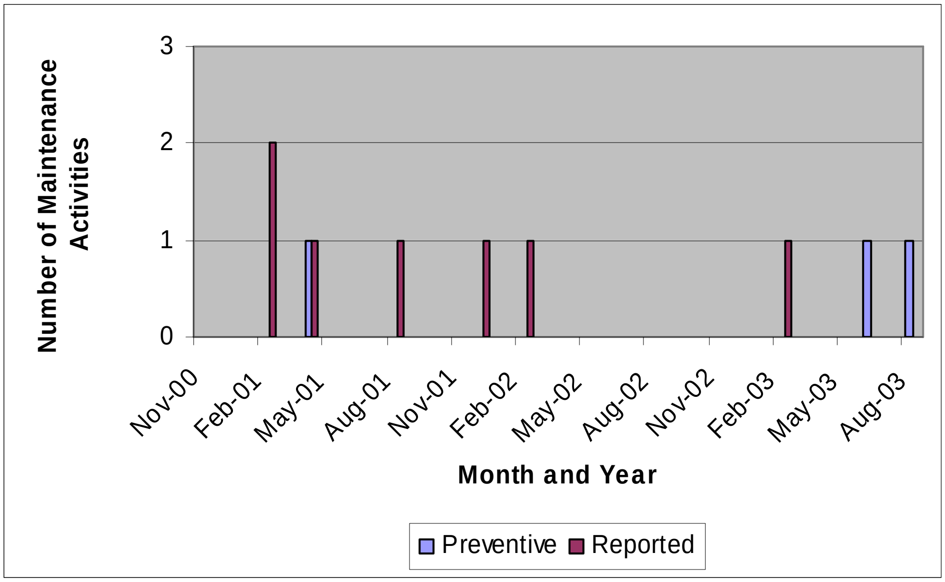


Table 5-20: Annual Average Downtime for Siskiyou Summit CCTV

Annual Average Downtime			
Primary Downtime		Preventive Maintenance Delay	
Days	Days / Problem	Days	Days / Problems
5	1	0	0

Estimated annual average costs of maintenance are presented in Table 5-21.

Table 5-21: Annual Average Costs for Siskiyou Summit CCTV

Site Location	Siskiyou Summit	
Annual Average Costs	Labor Cost	$445
	Transportation Costs	$0
	Replacement Costs	$0
	Operational Costs	$242
	Admin Costs	$0
	Total	$686

5.1.10. Siskiyou Pass, OR

This CCTV is located on Interstate 5 at Siskiyou Pass at milepost 5. The Siskiyou Pass CCTV maintenance data was collected for the time period between November 2000 and April 2002. Table 5-22 shows the maintenance activities for this site for the above time period. Table 5-23 contains the estimated annual average downtimes. Figure 5-9 shows the distribution of maintenance activities for this site.

Table 5-22: Maintenance Activities for Siskiyou Pass CCTV

Time Period 1	11/15/2000	4/2/2002
	Preventive	Reported
Nov-00		
Dec-00		
Jan-01	1	
Feb-01	1	1
Mar-01		
Apr-01		2
May-01		4
Jun-01		
Jul-01		1
Aug-01		1
Sep-01		
Oct-01	1	
Nov-01		
Dec-01		
Jan-02		
Feb-02		1
Apr-03		1
Annual Average	**2**	**8**

Figure 5-10: Maintenance Activity Distribution for Siskiyou Pass CCTV

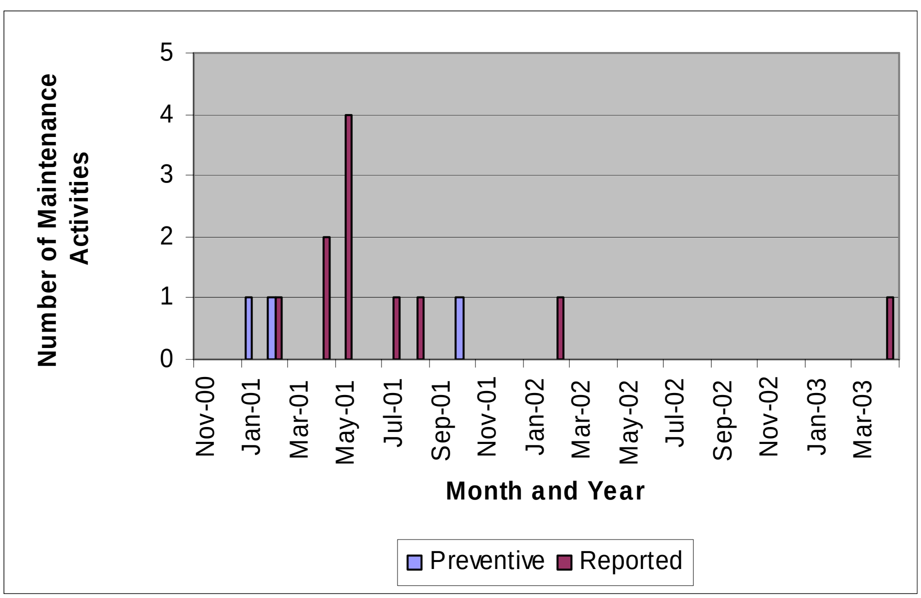


Table 5-23: Annual Average Downtime for Siskiyou Pass CCTV

Annual Average Downtime			
Primary Downtime		Preventive Maintenance Delay	
Days	Days / Problem	Days	Days / Problems
7	1	0	1

Estimated annual average costs of maintenance are presented in Table 5-24.

Table 5-24: Annual Average Costs for Siskiyou Pass CCTV

Site Location	Siskiyou Pass	
Annual Average Costs	Labor Cost	$79
	Transportation Costs	$73
	Replacement Costs	$37
	Operational Costs	$321
	Admin Costs	$0
	Total	$509

5.1.11. Other Selected Cameras in Oregon

There were a number of CCTV sites from Oregon for which the activity logs were not available. Table 5-25 shows a summary of the estimated annual average costs.

Table 5-25: Annual Average Costs for Other Oregon CCTV Sites

	Annual Average Costs					
Site Location	Labor Cost	Transportation Cost	Replacement Cost	Operational Cost	Admin Cost	Total
Willamette	$2,371	$788	$423	$350	$1,034	$4,967
Lake of the Woods	$2,242	$553	$273	$618	$164	$3,849
Warner MT.	$4,812	$1,293	$412	$387	$0	$6,904
Quartz MT.	$1,193	$434	$217	$0	$0	$1,844
Paisley	$691	$23	$12	$241	$26	$991
Santiam Pass	$3,137	$1,190	$519	$369	$786	$6,000

5.2. RWIS Case Studies

RWIS is also one of the most widely deployed ITS technologies in the nation. Road condition information from RWIS is fed into traveler information web pages that can be accessed by the motorists. They are widely used by state DOTs to monitor highway conditions and plan winter maintenance activities and have also been found extremely useful by highway users when provided to the public through the Internet.

The ME activity logs were the only data available for the California sites; these were collected for the time period between November 2002 and July 2003. There were no regular FEN checks for RWIS sites for this time period in Caltrans District 2[3]. Oregon does not have a scheduled regular check of RWIS or CCTV sites on a daily basis.

There were no regular FEN checks for RWIS sites for this time period in Caltrans District 2. But, Caltrans District 2 has started performing regular FEN checks for RWIS sites also along with CCTV sites recently. Oregon does not have any scheduled regular checks of RWIS or CCTV sites on a daily basis like the FEN checks at Caltrans District 2.

5.2.1. Oregon Mountain Summit, CA

Table 5-26 shows the number of different types of maintenance activities for the above time period. Figure 5-11 shows the distribution of the maintenance activities over the time period. Table 5-27 summarizes the annual average costs and downtime estimated from the data.

Table 5-26: Maintenance Activities for Oregon Mountain Summit RWIS

Month and Year	Preventive	Reported
Nov-02		1
Dec-02		1
Jan-03		
Feb-03		
Mar-03		
Apr-03		
May-03		
Jun-03	1	
Jul-03		1
Aug-03	1	
Annual Average	**2**	**4**

[3] Caltrans District 2 has recently started performing FEN checks for both RWIS sites and CCTV sites.

Figure 5-11: Maintenance Activity Distribution for Oregon Mountain Summit RWIS

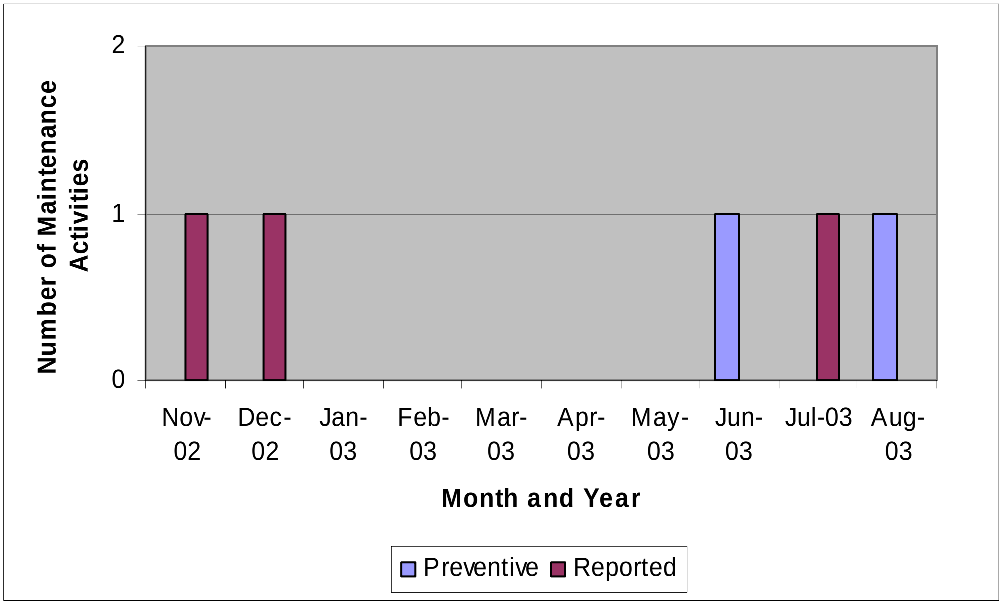


Table 5-27: Annual Average Costs and Downtime for Oregon Summit RWIS

HWY 299 OREGON MT SUMMIT		
Annual Average Costs	Labor Cost	$1,122
	Driver Cost	$530
	Vehicle Cost	$124
	Replacement Costs	$0
	Total Cost	$1,776
Annual Average Down Time (Primary)	Days	30
	Days / Activity	4

5.2.2. Snowman Hill, CA

Table 5-28 shows the number of different types of maintenance activities for the above time period. Figure 5-12 shows the distribution of the maintenance activities over the time period. Table 5-29 summarizes the annual average costs and downtime estimated from the data.

Table 5-28: Maintenance Activities for Snowman Hill RWIS

Month and Year	Preventive	Reported
Nov-02		
Dec-02	1	
Jan-03		2
Feb-03		1
Mar-03		
Apr-03		
May-03	1	
Jun-03		1
Jul-03		1
Aug-03		
Annual Average	**2**	**6**

Figure 5-12: Maintenance Activity Distribution for Snowman Hill RWIS

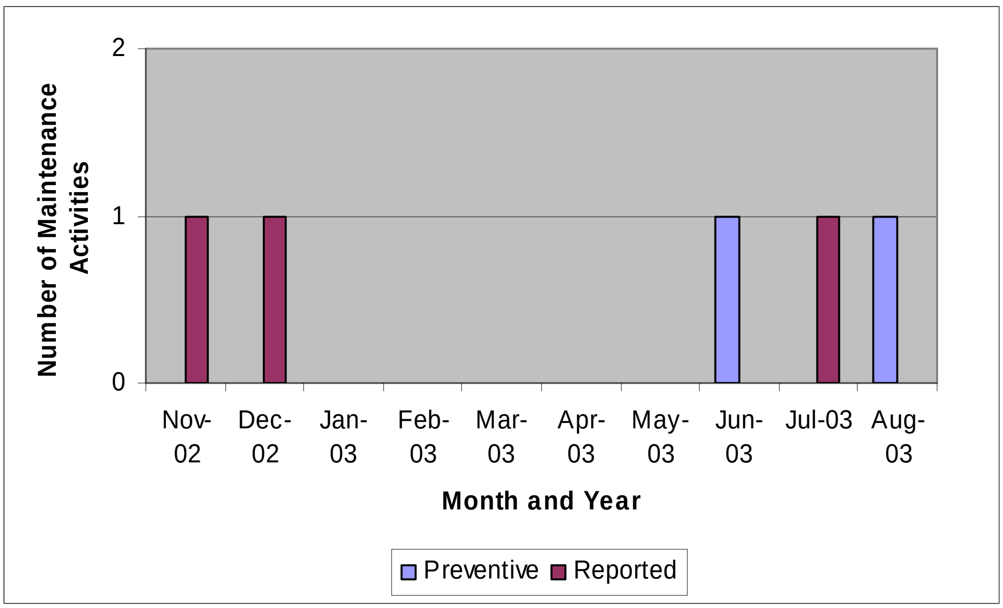


Table 5-29: Annual Average Costs and Downtime for Snowman Hill RWIS

HWY 89 @ SNOWMANS		
Annual Average Costs	Labor Cost	$756
	Driver Cost	$670
	Vehicle Cost	$182
	Replacement Costs	$0
	Total Cost	$1,609
Annual Average Down Time (Primary)	Days	28
	Days / Activity	3

5.2.3. Black Butte Summit, CA

Table 5-30 shows the number of different types of maintenance activities for the above time period. Figure 5-13 shows the distribution of the maintenance activities over the time period. Table 5-31 summarizes the annual average costs and downtime estimated from the data.

Table 5-30: Maintenance Activities for Black Butte Summit RWIS

Month and Year	Preventive	Reported
Nov-02		
Dec-02		
Jan-03		
Feb-03		
Mar-03		
Apr-03		
May-03	1	
Jun-03		
Jul-03		
Aug-03		2
Annual Average	1	2

Figure 5-13: Maintenance Activity Distribution for Black Butte Summit RWIS

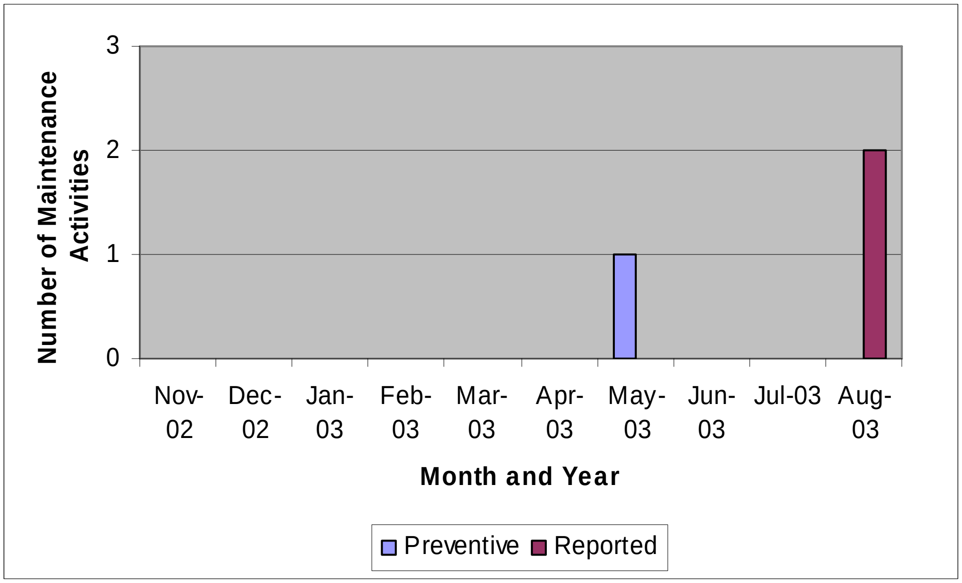


Table 5-31: Annual Average Costs and Downtime for Black Butte RWIS

5 SB @ Black Butte		
Annual Average Costs	Labor Cost	$26
	Driver Cost	$0
	Vehicle Cost	$0
	Replacement Costs	$0
	Total Cost	$26
Annual Average Down Time (Primary)	Days	24
	Days / Activity	6

5.2.4. Siskiyou Summit, OR

This RWIS site is located on Interstate 5 at milepost 4.5. The Siskiyou Summit RWIS maintenance data was collected for the time period between February 2003 and April 2003. The annual estimates shown here are normalized for the time period variations among different sites. Table 5-32 shows the maintenance activities for this site for the above time period. Table 5-33 contains the estimated annual average downtimes. Figure 5-14 shows the distribution of maintenance activities for this site.

Table 5-32: Maintenance Activities for Siskiyou Summit RWIS

Time Period 1	2/3/2003	4/14/2003
	Preventive	Reported
Feb-03		2
Mar-03		1
Apr-03		1
Annual Average	0	9

Figure 5-14: Maintenance Activity Distribution for Siskiyou Summit RWIS

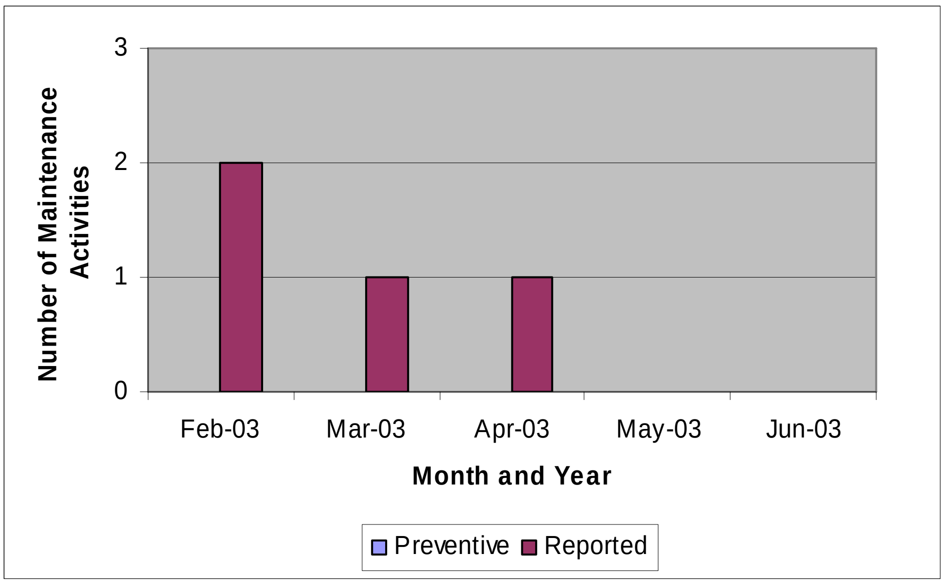


Table 5-33: Annual Average Downtime for Siskiyou Summit RWIS

Annual Average Downtime			
Primary Downtime		Preventive Maintenance Delay	
Days	Days / Problem	Days	Days / Problems
26	2	0	0

Estimated annual average costs of maintenance are presented in Table 5-24. These estimates are based on the bi-annual budget data for FY 01-02 and FY 02-03.

Table 5-34: Annual Average Costs for Siskiyou Summit RWIS

Site Location	Siskiyou Summit	
Annual Average Costs	Labor Cost	$457
	Transportation Costs	$2,095
	Replacement Costs	$1,047
	Operational Costs	$0
	Admin Costs	$0
	Total	$3,599

5.2.5. Other RWIS sites in Oregon

There were other selected RWIS sites in Oregon that had no maintenance activity log information available. A summary of estimated annual average costs for these sites are provided in Table 5-35.

Table 5-35: Annual Average Costs for Other RWIS Sites in Oregon

	Annual Average Costs					
Site Location	Labor Cost	Transportation Costs	Replacement Costs	Operational Costs	Admin Costs	Total
Willamette	$141	$535	$267	$0	$0	$943
Port Orford	$1,008	$632	$316	$0	$0	$1,955
Ward Butte	$208	$188	$94	$0	$430	$919
Lake of the Woods	$49	$49	$0	$0	$0	$98
Warner MT.	$84	$84	$0	$0	$0	$169
Quartz MT.	$0	$0	$0	$0	$0	$0
Paisley	$136	$7	$7	$0	$0	$150
Santiam Pass	$0	$0	$0	$0	$0	$0

5.3. CMS / VMS Case Studies

State DOTs have been using electronic signs to provide motorists with useful information and warn motorists of hazardous conditions. The messages through electronic signs have been found to be more effective than regular static traffic signs in communicating messages to drivers. The ME activity logs were the only data available for these sites and were collected for the time period between November 2002 and July 2003.

5.3.1. Interstate 5 Northbound at Ream Road, CA

Table 5-36 shows the number of different types of maintenance activities for the above time period. Figure 5-15 shows the distribution of the maintenance activities over the time period. Table 5-37 summarizes the annual average costs and downtime estimated from the data.

Table 5-36: Maintenance Activities for Ream Road CMS

Month and Year	Preventive	Reported
Nov-02	2	
Dec-02	1	
Jan-03	1	1
Feb-03		
Mar-03	1	1
Apr-03		
May-03	1	
Jun-03		
Jul-03	1	
Aug-03		
Annual Average	8	2

Figure 5-15: Maintenance Activity Distribution for Ream Road CMS

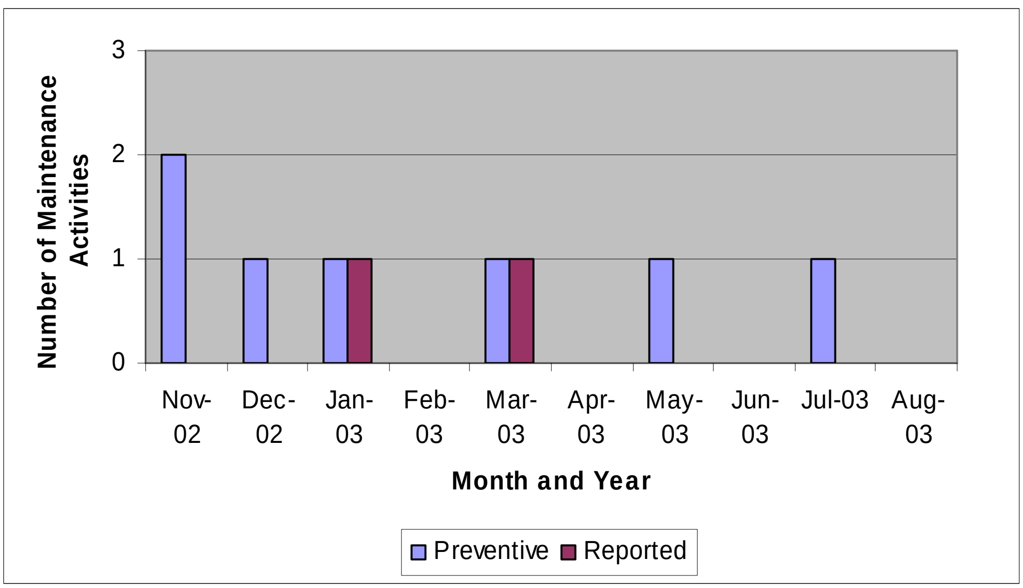


Table 5-37: Annual Average Costs and Downtime for Ream Road CMS

5 NB REAM ROAD OC		
Annual Average Costs	Labor Cost	$451
	Driver Cost	$296
	Travel Cost	$58
	Replacement Costs	$0
	Total Cost	$805
Annual Average Down Time (Primary)	Days	10
	Days / Activity	4

5.3.2. Interstate 5 Southbound at Walters Road, CA

Table 5-38 shows the number of different types of maintenance activities for the above time period. Figure 5-15 shows the distribution of the maintenance activities over the time period. Table 5-39 summarizes the annual average costs and downtime estimated from the data.

Table 5-38: Maintenance Activities for Walter Road CMS

Month and Year	Preventive	Reported
Nov-02	1	
Dec-02	1	
Jan-03	1	
Feb-03		
Mar-03	1	
Apr-03		
May-03	1	
Jun-03		
Jul-03	1	
Aug-03		
Annual Average	**7**	**0**

Figure 5-16: Maintenance Activity Distribution for Walters Road CMS

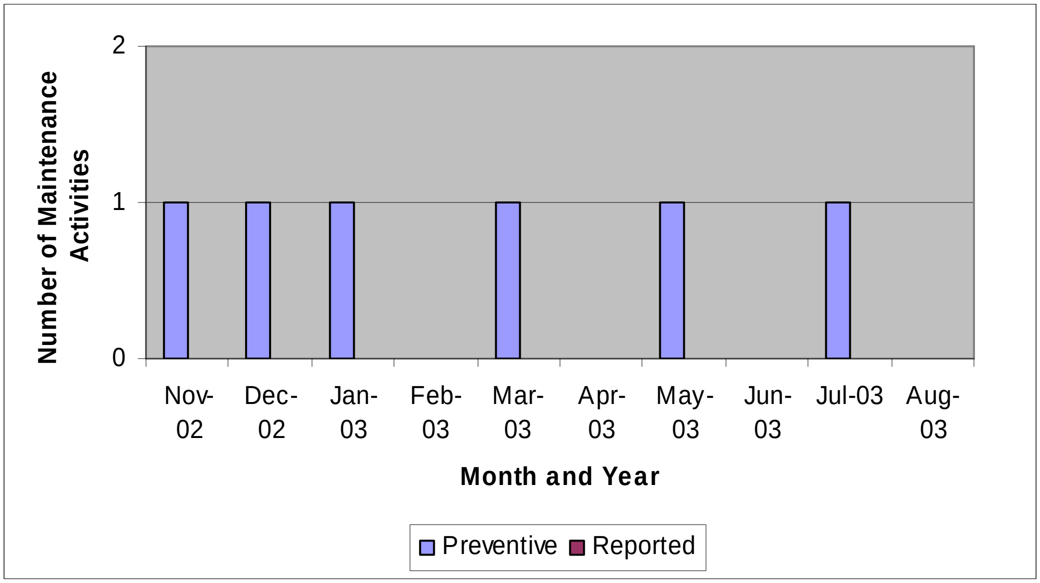


Table 5-39: Annual Average Costs and Downtime for Walters Road CMS

SB @ WALTERS ROAD OC(CMS)		
Annual Average Costs	Labor Cost	$239
	Driver Cost	$32
	Travel Cost	$8
	Replacement Costs	$0
	Total Cost	$279
Annual Average Down Time (Primary)	Days	8
	Days / Activity	1

5.3.3. Interstate 5 Northbound at Smith Road, CA

Table 5-40 shows the number of different types of maintenance activities for the above time period. Figure 5-17 shows the distribution of the maintenance activities over the time period. Table 5-41 summarizes the annual average costs and downtime estimated from the data.

Table 5-40: Maintenance Activities for Smith Road CMS

Month and Year	Preventive	Reported
Nov-02	1	
Dec-02	1	
Jan-03	1	
Feb-03		
Mar-03	1	1
Apr-03		
May-03	1	
Jun-03		
Jul-03	1	
Aug-03		
Annual Average	**7**	**1**

Figure 5-17: Maintenance Activity Distribution for Smith Road CMS

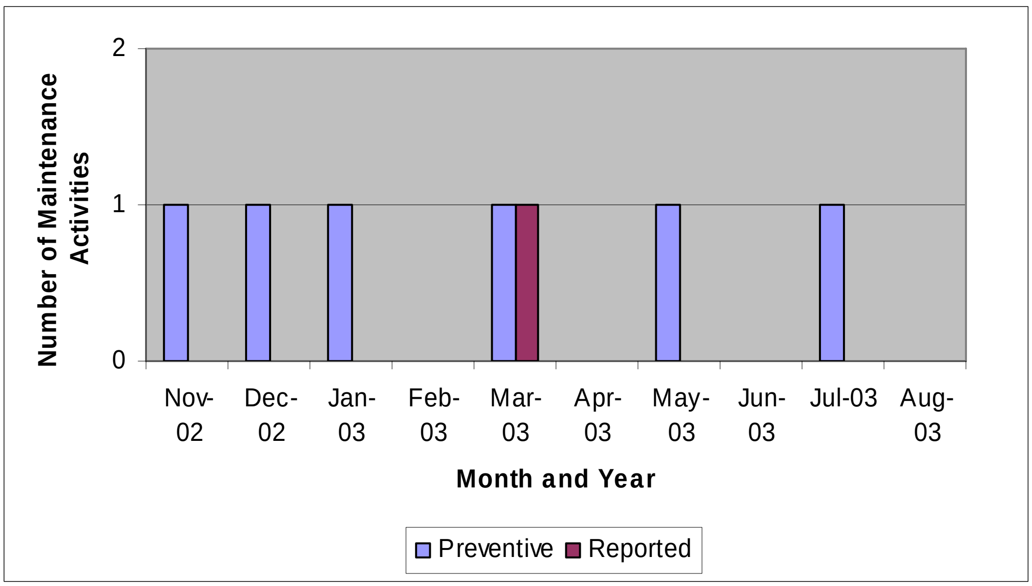


Table 5-41: Annual Average Costs and Downtime for Smith Road CMS

NB 5 ON SMITH RD OVERCROSS(CMS)		
Annual Average Costs	Labor Cost	$326
	Driver Cost	$179
	Travel Cost	$51
	Replacement Costs	$0
	Total Cost	$556
Annual Average Down Time (Primary)	Days	1
	Days / Activity	1

5.3.4. Radar CMS at Sidehill, CA

Table 5-42 shows the number of different types of maintenance activities for the above time period. Figure 5-18 shows the distribution of the maintenance activities over the time period. Table 5-43 summarizes the annual average costs and downtime estimated from the data.

Table 5-42: Maintenance Activities for Sidehill Radar CMS

Month and Year	Preventive	Reported
Nov-02		1
Dec-02	1	
Jan-03	1	1
Feb-03		
Mar-03	1	
Apr-03		
May-03	1	
Jun-03		
Jul-03	1	
Aug-03		
Annual Average	**6**	**2**

Figure 5-18: Maintenance Activity Distribution for Sidehill Radar CMS

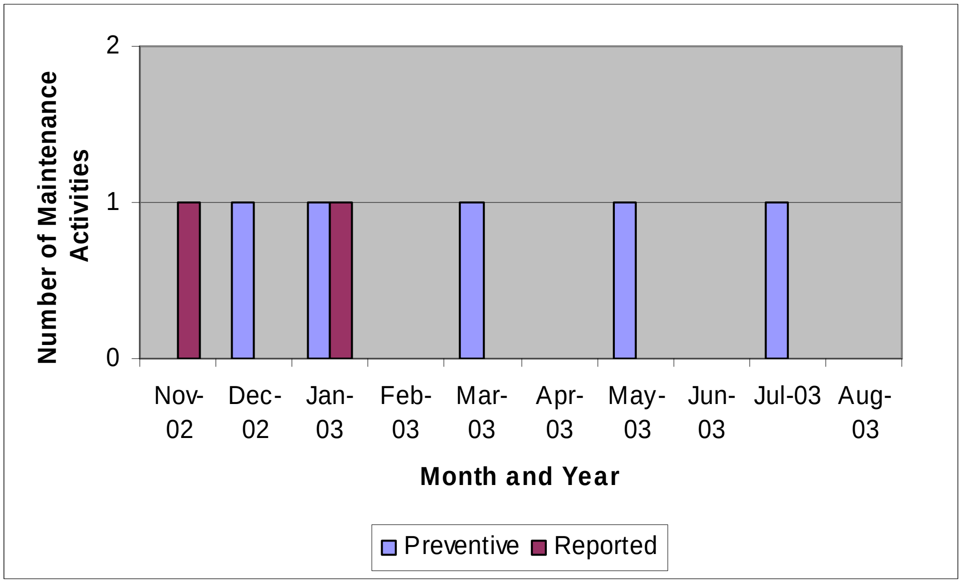


Table 5-43: Annual Average Costs and Downtime for Sidehill Radar CMS

SIDESHILL(Portable CMS)		
Annual Average Costs	Labor Cost	$276
	Driver Cost	$252
	Travel Cost	$55
	Replacement Costs	$0
	Total Cost	$583
Annual Average Down Time (Primary)	Days	11
	Days / Activity	4

5.3.5. Radar CMS at Lamoine, CA

Table 5-44 shows the number of different types of maintenance activities for the above time period. Figure 5-19 shows the distribution of the maintenance activities over the time period. Table 5-45 summarizes the annual average costs and downtime estimated from the data.

Table 5-44: Maintenance Activities for Lamoine Radar CMS

Month and Year	Preventive	Reported
Nov-02		
Dec-02	1	
Jan-03		
Feb-03	1	
Mar-03	1	
Apr-03		
May-03	1	
Jun-03		
Jul-03	1	3
Aug-03		
Annual Average	**6**	**4**

Figure 5-19: Maintenance Activity Distribution for Lamoine Radar CMS

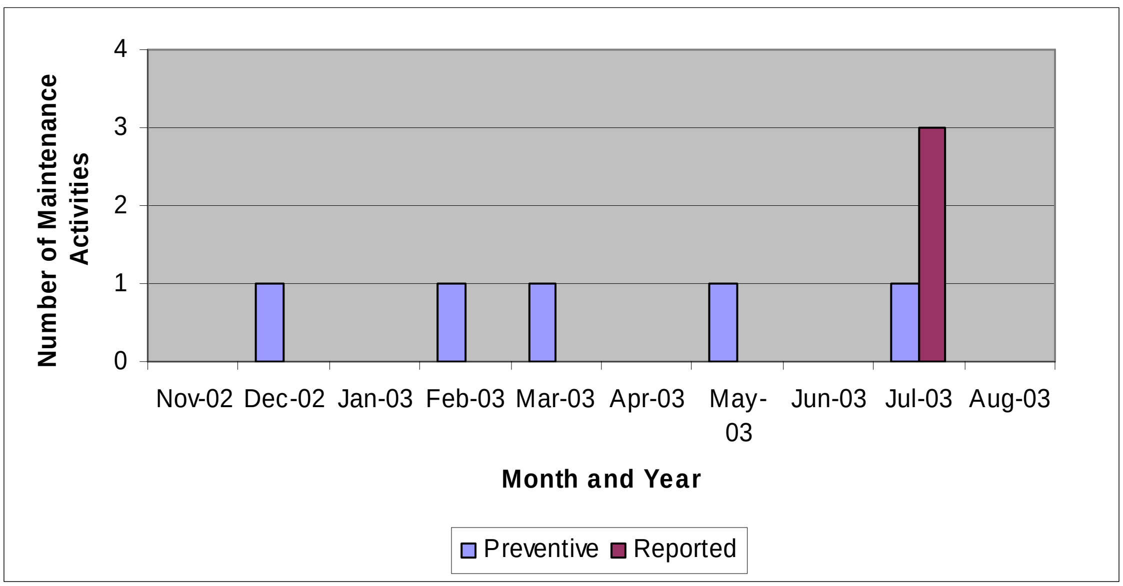


Table 5-45: Annual Average Costs and Downtime for Lamoine Radar CMS

SIDE HILL(Portable CMS)		
Annual Average Costs	Labor Cost	$2,703
	Driver Cost	$298
	Travel Cost	$146
	Replacement Costs	$0
	Total Cost	$3,147
Annual Average Down Time (Primary)	Days	17
	Days / Activity	4

5.3.6. Portable VMS at Bailey Hill (CA), OR

This portable VMS is owned, operated and maintained by ODOT, though the sign is usually located at Bailey Hill in California along Interstate 5. Bailey Hill is about 2 miles from the California side of the California-Oregon border. The Bailey Hill PVMS Maintenance data was collected for the time period between April 2001 and January 2002. The annual estimates shown here are normalized for the time period variations among different sites. Table 5-46 shows the maintenance activities for this site for the above time period. Table 5-47 contains the estimated annual average downtimes. Figure 5-20 shows the distribution of maintenance activities for this site.

Table 5-46: Maintenance Activities for Bailey Hill PVMS

Time Period 1	4/27/2001	1/28/2002
	Preventive	**Reported**
Apr-01	1	
May-01		
Jun-01	1	1
Jul-01		
Aug-01		2
Sep-01		
Oct-01		
Nov-01		2
Dec-01		
Jan-02		2
Annual Average	**3**	**9**

Figure 5-20: Maintenance Activity Distribution for Bailey Hill PVMS

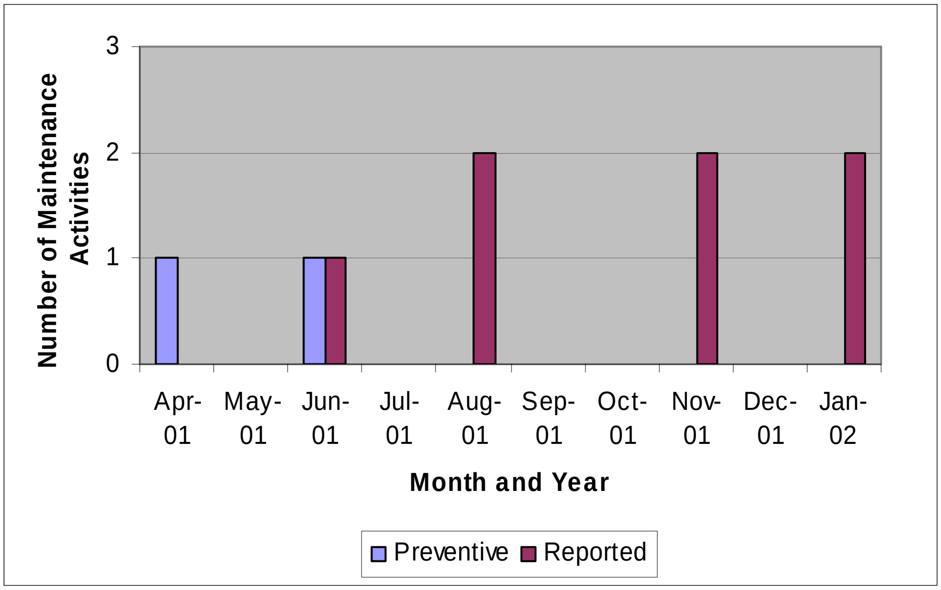


Table 5-47: Annual Average Downtime for Bailey Hill PVMS

Annual Average Downtime			
Primary Downtime		Preventive Maintenance Delay	
Days	Days / Problem	Days	Days / Problems
42	13	3	1

The bi-annual budget data for this site was not collected, so, the annual maintenance cost information is not provided here.

5.3.7. Portable VMS at Hilt (CA), OR

This portable VMS is owned, operated and maintained by ODOT, though the sign is usually located at Hilt in California along Interstate 5. Hilt is about 5 miles from the California side of the California-Oregon border. The time periods for which these activities were available were different for each of the sites. The Hilt PVMS maintenance data was collected for the time period between March 2001 and February 2002. The annual estimates shown here are normalized for the time period variations among different sites. Table 5-48 shows the maintenance activities for this site for the above time period. Table 5-47 contains the estimated annual average downtimes. Figure 5-20 shows the distribution of maintenance activities for this site.

Table 5-48: Maintenance Activities for Hilt PVMS

Time Period	3/29/2001	2/4/2002
	Preventive	**Reported**
Mar-01		1
Apr-01	1	
May-01		
Jun-01		1
Jul-01		
Aug-01		
Sep-01		
Oct-01		
Nov-01		1
Dec-01		
Jan-02		
Annual Average	**1**	**4**

Figure 5-21: Maintenance Activity Distribution for Hilt PVMS

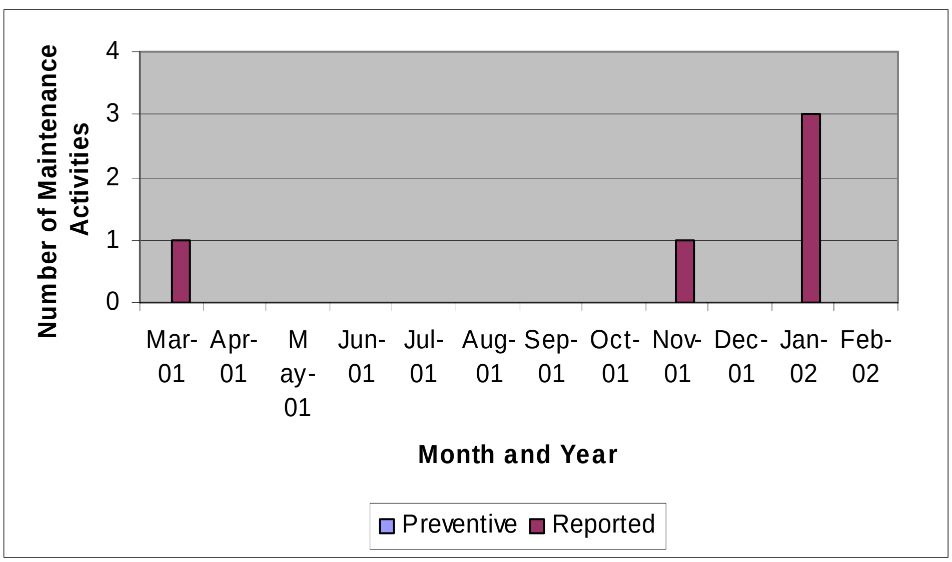


Table 5-49: Annual Average Downtime for Hilt PVMS

Annual Average Downtime			
Primary Downtime		Preventive Maintenance Delay	
Days	Days / Problem	Days	Days / Problems
8	1	1	1

The bi-annual budget data for this site was not collected, so the annual maintenance cost information is not provided here.

5.3.8. VMS at Klamath Falls, OR

This VMS is located at Klamath Falls in Oregon along Highway 140 at milepost 63. The Klamath Falls VMS maintenance data was collected for the time period between July 2002 and May 2003. The annual estimates shown here are normalized for the time period variations among different sites. Table 5-50 shows the maintenance activities for this site for the above time period. Table 5-51 contains the estimated annual average downtimes. Figure 5-22 shows the distribution of maintenance activities for this site.

Table 5-50: Maintenance Activities for Klamath Falls VMS

Time Period 1	7/1/2002	5/31/2003
	Preventive	Reported
Jul-02	1	1
Aug-02		
Sep-02		
Oct-02		
Nov-02		
Dec-02		
Jan-03		
Feb-03	1	
Mar-03		
Apr-03		2
Annual Average	8	12

Figure 5-22: Maintenance Activity Distribution for Klamath Falls VMS

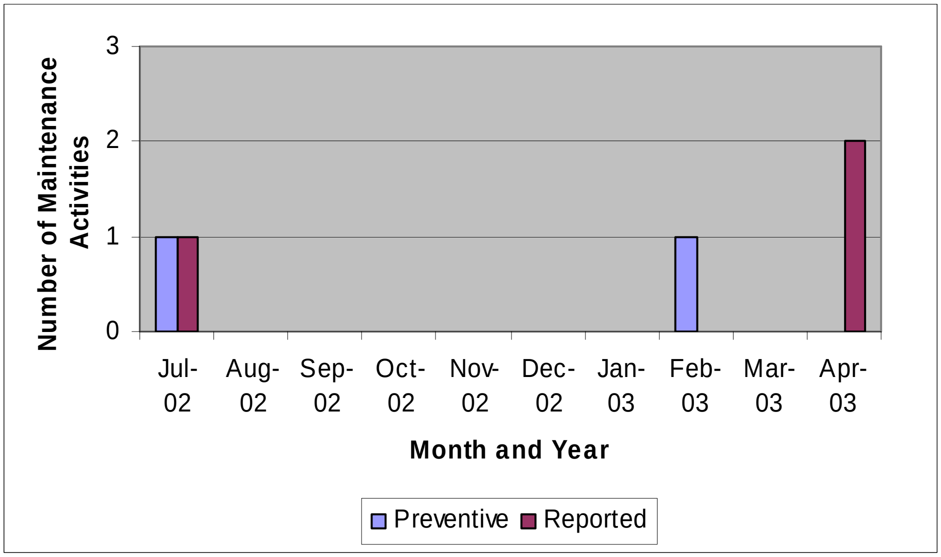


Table 5-51: Annual Average Downtime for Klamath Falls VMS

Annual Average Downtime			
Primary Downtime		Preventive Maintenance Delay	
Days	Days / Problem	Days	Days / Problems
32	8	12	3

The bi-annual budget data for this site was not available, so the annual average maintenance cost estimates are not provided here.

5.3.9. VMS at Medford, OR

This VMS is located at Medford in Oregon along Highway 140 at milepost 13.8. The Medford VMS maintenance data was collected for the time period between February 2003 and October 2003. The annual estimates shown here are normalized for the time period variations among different sites. Table 5-52 shows the maintenance activities for this site for the above time period. Table 5-53 contains the estimated annual average downtimes. Figure 5-23 shows the distribution of maintenance activities for this site.

Table 5-52: Maintenance Activities for Medford VMS

Time Period	2/19/2003	10/10/2003
	Preventive	**Reported**
Nov-02		
Dec-02		
Jan-03		
Feb-03	1	
Mar-03		
Apr-03		
May-03		
Jun-03		
Jul-03		
Aug-03		
Sep-03		
Oct-03		
Nov-03		
Dec-03		
Annual Average	**2**	**0**

Figure 5-23: Maintenance Activity Distribution for Medford VMS

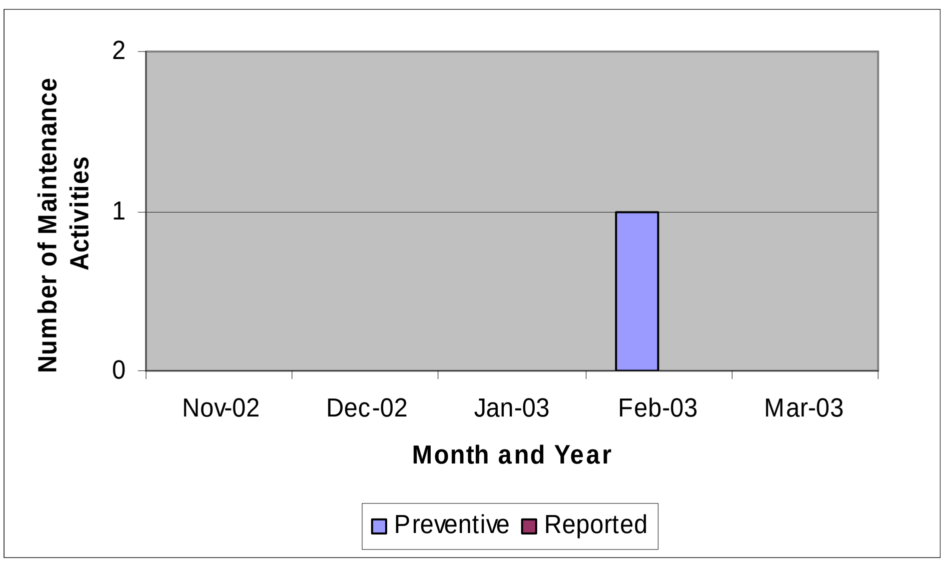


Table 5-53: Annual Average Downtime for Medford VMS

Annual Average Downtime			
Primary Downtime		Preventive Maintenance Delay	
Days	Days / Problem	Days	Days / Problems
2	1	1	1

The bi-annual budget data for this site was not available, so the annual average maintenance cost estimates are not provided here.

5.3.10. Other VMS Sites in Oregon

Some of the selected VMS sites in Oregon did not have maintenance activity records readily available. A summary of the estimated annual average maintenance costs for these sites is provided in Table 5-54.

Table 5-54: Annual Average Downtime for Other VMS Sites in Oregon

	Annual Average Costs					
Site Location	Labor Cost	Transportation Costs	Replacement Costs	Operational Costs	Admin Costs	Total
Lake of the Woods VMS 1	$65	$73	$36	$0	$0	$173
Lake of the Woods VMS 2	$872	$167	$84	$0	$0	$1,123

5.4. Highway Advisory Radio and Other Case Studies

HAR was the next most prevalent technology in the COATS study area. The ME activity logs were the only data available for these sites and were collected for the time period between November 2002 and July 2003. Bi-annual budget data for FY 01-02 and FY 02-03 was the only data used for Oregon case studies of HAR and other technologies.

5.4.1. HAR at Long Valley Agriculture Inspection Station, CA

Table 5-55 shows the number of different types of maintenance activities for the above time period. Figure 5-24 shows the distribution of the maintenance activities over the time period. Table 5-56 summarizes the annual average costs and downtime estimated from the data.

Table 5-55: Maintenance Activities for Long Valley HAR

Month and Year	Preventive	Reported
Nov-02	1	
Dec-02	1	
Jan-03	1	
Feb-03		
Mar-03	1	
Apr-03		1
May-03	1	1
Jun-03		
Jul-03	1	3
Aug-03		1
Annual Average	**7**	**7**

Figure 5-24: Maintenance Activity Distribution for Long Valley HAR

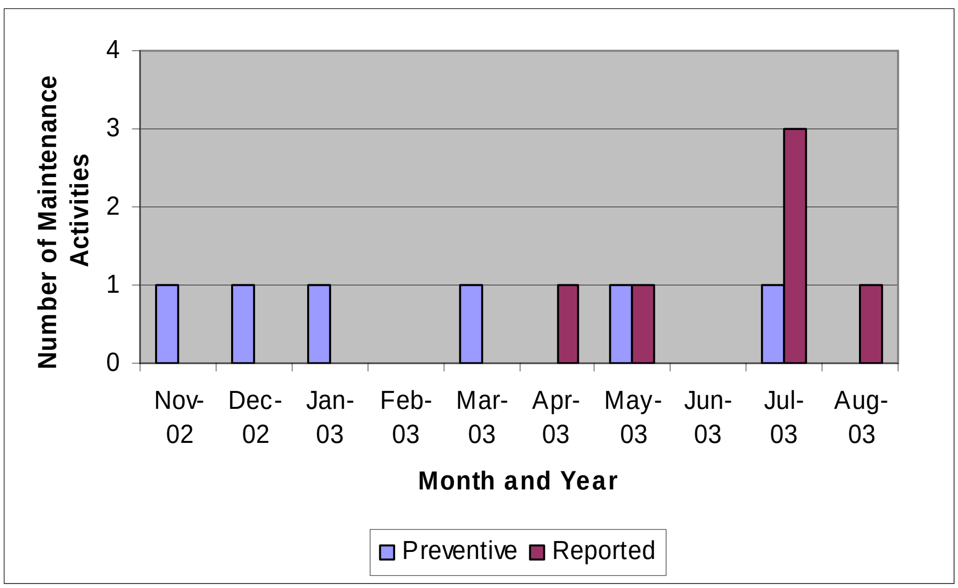


Table 5-56: Annual Average Costs and Downtime for Long Valley HAR

LONG VALLEY AGG INSPECTION STATION		
Annual Average Costs	Labor Cost	$1,722
	Driver Cost	$1,499
	Travel Cost	$238
	Replacement Costs	$0
	Total Cost	$3,459
Annual Average Down Time (Primary)	Days	82
	Days / Activity	10

5.4.2. HAR at Four Corners, CA

Table 5-57 shows the number of different types of maintenance activities for the above time period. Figure 5-25 shows the distribution of the maintenance activities over the time period. Table 5-58 summarizes the annual average costs and downtime estimated from the data.

Table 5-57: Maintenance Activities for Four Corners HAR

Month and Year	Preventive	Reported
Nov-02		
Dec-02	1	1
Jan-03	1	
Feb-03		
Mar-03	1	
Apr-03		1
May-03	1	1
Jun-03		1
Jul-03	1	1
Aug-03	1	
Annual Average	**7**	**6**

Figure 5-25: Maintenance Activity Distribution for Four Corners HAR

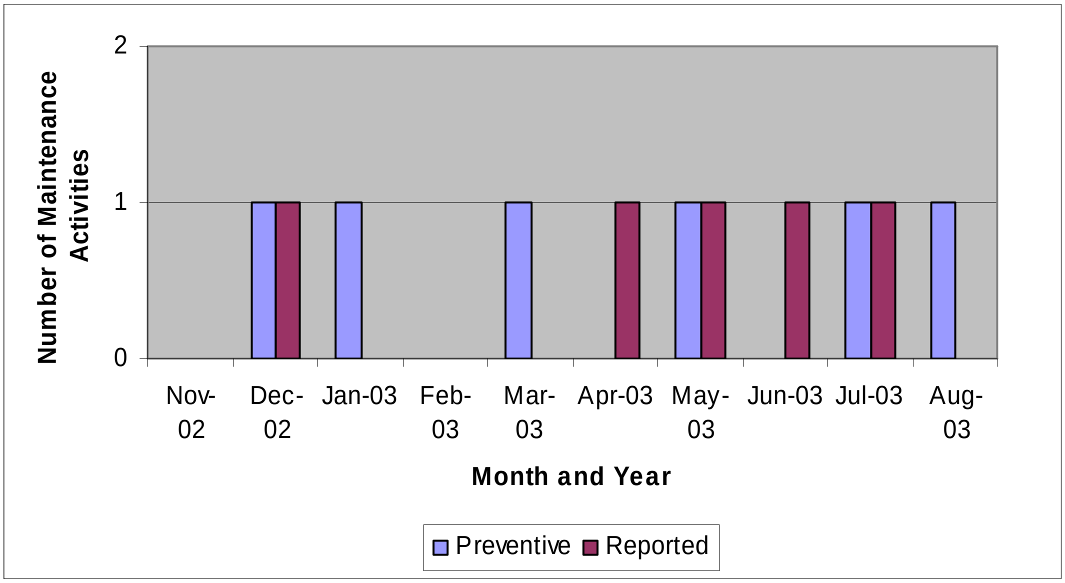


Table 5-58: Annual Average Costs and Downtime for Four Corners HAR

FOUR CORNERS, JCT R TE 89		
Annual Average Costs	Labor Cost	$1,680
	Driver Cost	$663
	Travel Cost	$191
	Replacement Costs	$0
	Total Cost	$2,534
Annual Average Down Time (Primary)	Days	7
	Days / Activity	1

5.4.3. Rural Traffic Management Center (TMC) at District 2, CA

The CCTV activity logs were the only data available for the Redding TMC, and this data was collected for the time period between November 2002 and June 2004. Almost all of these maintenance activities were preventive in nature. A verification of the field elements (i.e. FEN check) is performed every day, once in the morning and once in the evening. There were few maintenance activities (e.g. updating software at TMC or replacing a malfunctioning router). Table 5-59 summarizes the annual average costs and downtime estimated from the data for the above time period. The primary downtime indicated here is the system downtime for reported problems. It should be noted that the cost information presented here covers only the costs related to regular FEN check and not any other activities. Therefore, the costs presented here for Regional TMC at Redding can be considered to be the part of the operating costs of the Redding TMC.

Table 5-59: Annual Average Costs and Downtime for Redding TMC

Site Location	Redding TMC		
Average Annual Costs	Total Cost		$14,922
	Labor Cost		$14,922
	Replacement Costs		$0
Average Annual Downtime	Primary	Days	0
		Hours	28:50:00

5.4.4. HAR at Ashland, OR

This Highway Advisory Radio (HAR) is located at Ashland in Oregon along Interstate 5 at milepost 16. The Ashland HAR maintenance data was collected for the time period between November 2001 and October 2003. The annual estimates shown here are normalized for the time period variations among different sites. Table 5-60 shows the maintenance activities for this site for the above time period. Table 5-61 contains the estimated annual average downtimes. Figure 5-26 shows the distribution of maintenance activities for this site.

Table 5-60: Maintenance Activities for Ashland HAR

Time Period 1	11/27/2001	10/10/2003
	Preventive	**Reported**
Nov-01	1	
Dec-01		
Jan-02		
Feb-02	1	
Mar-02		
Apr-02		
May-02		
Jun-02		
Jul-02		
Aug-02		
Sep-02		
Oct-02		
Nov-02		1
Dec-02		
Sep-03		1
Annual Average	**1**	**1**

Figure 5-26: Maintenance Activity Distribution for Ashland HAR

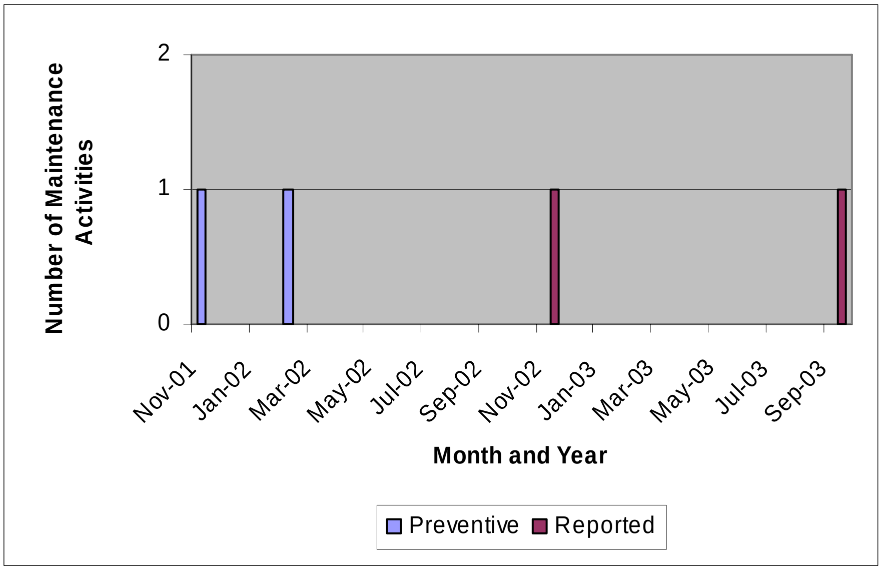


Table 5-61: Annual Average Downtime for Ashland HAR

Annual Average Downtime			
Primary Downtime		Preventive Maintenance Delay	
Days	Days / Problem	Days	Days / Problems
15	7	2	2

The bi-annual budget data for this site was collected for FY 01-02 and FY 02-03. Estimated annual average maintenance costs are provided in Table 5-62.

Table 5-62: Annual Average Costs for Ashland HAR

Site Location	Ashland HAR	
Annual Average Costs	Labor Cost	$1,525
	Transportation Costs	$1,649
	Replacement Costs	$1,649
	Operational Costs	$215
	Admin Costs	$0
	Total	$5,038

Details on the type of type of communication and power used along with estimated costs per trip are provided in Appendix C.

6. SUMMARY AND CONCLUSIONS

ITS maintenance costs, downtimes and problem frequencies for selected sites in COATS study area are presented here as individual case studies, because maintenance needs and associated costs vary significantly from one site to another. The intention of the work presented here is not to provide one average number for maintenance cost and expected frequency of problems needing maintenance and downtimes but provide information on individual sites. A summary of the above case studies is presented here.

6.1. CCTV Case Studies

CCTV technology is the most widely deployed ITS technology in the COATS region. The case studies in this study included a total of 16 CCTV sites in the COATS region. A correlation between travel time to the site and annual average transportation costs could not be established. The travel costs are predominantly dependent on the total number of maintenance activities per year. Operations costs (e.g. power and communications costs) and replacement costs (i.e. costs of any parts replaced) were not available for California sites. Table 6-1 presents the average values of annual average costs and downtimes across all the sites for each state.

Table 6-1: Summary of CCTV Case Studies

	Average Annual Cost							Down Time			
	Total Cost	Transportation Cost		Labor Cost	Operations Cost	Admin Costs	Replacement Cost	Primary Downtime		Preventive Maintenance Delay	
		Driver Costs	Vehicle Costs					Days	Hours or Days / Activity	Days	Days / Activity
CA	**6 Sites**										
Avg.	$2,236	$149	$267	$1,820				19	12:26:42	6	1
Std. Dev.	$1,422	$82	$276	$1,228				30.3	3:06:09	2.6	0.3
OR	**10 Sites**										
Avg.	$2,844	$512		$1,583	$319	$203	$227	8	2	1	1
Std. Dev.	$2,385	$459		$1,535	$156	$380	$183	2.9	0.6	1.4	1.3

6.2. RWIS Case Studies

Case studies in this study include nine RWIS sites in Oregon and three RWIS sites in California. A correlation between travel time to the site and annual average transportation costs could not be established. The travel costs are predominantly dependent on the total number of maintenance activities per year. Operations costs (e.g. power and communications costs) and replacement costs (i.e. costs of any parts replaced) were not available for California sites. Table 6-2 shows the average values of annual costs and downtimes across all the sites for each state. Operations cost information was not available for California sites. The zero operations cost shown for Oregon sites does **not** indicate that there were no costs for power and communication. The bi-annual budgets did not capture all of the power and communication costs for RWIS sites. The power and communication bills were sometimes paid by the local maintenance yards and were also paid as one bill combined with other devices in the same location. Only one of the RWIS sites from Oregon had activity logs available. Therefore, no standard deviations for the down times are provided as there are only estimations available for one site in Oregon (i.e. Siskiyou Summit).

Table 6-2: Summary of RWIS Case Studies

	Average Annual Cost							Down Time			
	Total Cost	Transportation Cost		Labor Cost	Operations Cost	Admin Costs	Replacement Cost	Primary Downtime		Preventive Maintenance Delay	
		Driver Costs	Vehcile Costs					Days	Days / Activity	Days	Days / Activity
CA	**3 Sites**										
Avg.	$1,137	$400	$102	$635				27	4		
Std. Dev.	$965	$353	$93	$558				2.9	1.4		
OR	**9 Sites**										
Avg.	$870	$399		$231	$0	$48	$192	26	2	0	0
Std. Dev.	$1,212	$679		$323	$0	$143	$344				

6.3. CMS / VMS Case Studies

There are two CMS and three radar CMS sites from California included in this study. Two portable VMS and four other VMS sites in Oregon are also included here. The information on costs and downtimes are provided separately for the CMS / VMS sites and portable CMS / VMS sites since some of the cost information is significantly different for the two categories. There was no cost information available for the two portable VMS sites in Oregon. Table 6-3 shows the average values of annual costs and downtimes across all the sites for each state.

Table 6-3: Summary of CMS / VMS Case Studies

	Average Annual Cost							Down Time			
	Total Cost	Transportation Cost		Labor Cost	Operations Cost	Admin Costs	Replacement Cost	Primary Downtime		Preventive Maintenance Delay	
		Driver Costs	Vehicle Costs					Days	Days / Activity	Days	Days / Activity
CA	**3 CMS Sites**										
Avg.	$418	$105	$29	$283				6	2		
Std. Dev.	$195	$103	$30	$62				4.7	1.7		
CA	**2 Radar CMS Sites**										
Avg.	$648	$242	$54	$351				14	4		
Std. Dev.	$137	$59	$4	$90				4.2	0.0		
OR	**2 VMS Sites**							**2 Other VMS Sites**			
Avg.	$648	$120		$468	$0	$0	$60	17	5	7	2
OR	**2 Portable VMS Sites**										
Avg.							$180	25	7	2	1

6.4. HAR and Other Case Studies

There were only two HAR sites from California and one site from Oregon included in this study. The cost and downtime information provided here is not statistically valid, so it cannot be extrapolated over time or to other sites. The information is provided to give the reader a sense of general costs and downtimes associated with HAR sites in rural areas. Table 6-4 shows the average values of annual average costs and downtimes across all the sites for each state.

Table 6-4: Summary of HAR Case Studies

	Average Annual Cost							Down Time			
	Total Cost	Transportation Cost		Labor Cost	Operations Cost	Admin Costs	Replacement Cost	Primary Downtime		Preventive Maintenance Delay	
		Driver Costs	Vehcile Costs					Days	Days / Activity	Days	Days / Activity
CA	**2 Sites**										
Avg.	$2,997	$1,081	$215	$1,701				45	6		
OR	**1 Site**										
Avg.	$5,038	$1,649		$1,525	$215	$0	$1,649	15	7	2	2

The Redding TMC was also included in this study. It is recommended that the information provided earlier in the individual case study as part of Chapter 5 should not be extrapolated over time or to other sites since the information only applies to one part of the TMC operations over a time period of two years.

6.5. Conclusions

Caltrans District 2 performs some preventive maintenance of their ITS deployments. Oregon also performs some preventive maintenance of their ITS deployments, though it does not have a formal preventive maintenance program. A checklist used for preventive maintenance in ODOT Region 4 of ITS field elements is shown in Appendix D. This checklist was provided by James Wittenberg (JAWS), Regional ITS coordinator for Region 4. As indicated in the literature cited in Chapter 2, a preventive maintenance program is expected to reduce the life cycle costs. The transportation cost component constitutes a significant percentage of the annual maintenance costs. It can be seen from the maintenance activity descriptions in the activity logs that the most common type of reported problems are related to power and communication and not component failures. So, the transportation component of the maintenance costs should be considered while selecting power and communication options for remote ITS field elements. Neither Caltrans nor Oregon currently uses any contracting for maintaining their field elements in the COATS study area. So, it was not possible to make a comparison between in-house ITS maintenance and contracted ITS maintenance.

This study summarily covers the training needs for ITS maintenance staff, estimates of annual average labor, transportation, replacement and operations costs, and estimates of downtime for various ITS field elements in rural areas. This information could be used for better budgeting, better training of staff and better planning of future ITS deployments, especially in rural areas. This study does not account for the varying priorities and performance standards of different ITS field elements in California and Oregon. So, Caution should be exercised in inferences involving comparison between the downtimes and costs of same ITS field elements from the two states.

While using the information contained in this report, it is important to note that the average annual maintenance costs and annual average downtimes are specific to these particular sites and are not necessarily representative samples for all of rural ITS field elements. So, the estimations for a given location other than the ones in this report will cost less or more to maintain and will also have less or more annual downtimes depending on the other factors including performance standards and priorities of ITS field elements.

6.6. Future Research

The sample size of this study (i.e. the number of case studies for each type of ITS field element) is too small for generalized conclusions on the expected annual maintenance costs or downtimes. A follow-up study that includes a complete set of CCTV, CMS, HAR and other technologies will be beneficial, especially for the purposes of better maintenance budgeting and planning.

The types of ITS deployments investigated in this study are the most common ITS deployments in COATS study area. As other types of ITS deployments become prevalent, a similar study of their maintenance needs will be useful. As estimates of the average maintenance costs are further refined, it may also be useful to investigate how this information could be used in budgeting for the future maintenance of ITS elements.

Another important research topic would be to investigate whether the maintenance costs and downtimes can be tracked through a more convenient system such as the one being implemented in Oregon. As better communication and power options for remote places become available, the cost information presented here may selectively be refined and used for life-cycle cost analysis to determine whether it is economical to switch to these improved options. The power and communication types used at the case study sites are provided in Appendix C of this document. This information can be used to analyze cost variations of different types of communication and power options. It will also be beneficial to evaluate the maintenance activity tracking system implemented by Oregon after one or two years of operation.

APPENDIX A

<u>Desired Skill Set of ITS Maintenance Personnel authored by Ian Turnbull, P.E. of Caltrans</u>:

Skills Category	Skills / Familiarity Areas
Broadcast / Industrial Video and Audio	NTSC video
	RGBHV video
	Video switching systems
	Display systems
	Sync systems
	Video encoders and decoders
	CCTV systems
Cabling and Facility Infrastructure	Structured cabling
	Cable termination techniques (cat5, coax, etc)
	Fiber installation, termination and test (MM and SM)
	Equipment room hardware (racks, cable ladder, etc)
LAN / WAN and General Telecommunications	Digital transmission
	Ethernet
	Router (function and configuration)
	Switches (function and configuration)
	Various telco transmission services (T1, frame relay, ISDN, POTS, ATM, etc)
	IP protocol suite
	7 layer OSI model
	Frequency division multiplexing
	Time division multiplexing
	Code division multiplexing
Microwave (Wireless)	Basic transmission (path calcs and propagation)
	Radio system functionality (system level)
	Radio spectrum and characteristics
	Licensed microwave and unlicensed ISM band interface types (Ethernet, T1, serial, analog video, etc.)
	Basic antennas and transmission lines
Basic Electrical (Power)	NEC issues
	Industry conventions
	Proper wiring practice
Programming	Ability to program in or understanding of a common language (e.g. C) and Understanding of Application Program Interface (API)
	General program structure
	HTML and web presentation
	Understanding of Java, Javascript, applets, etc.
Server Administration and Security	Basic understanding of functionality associated with fundamental network services (web, DNS, FTP, TFTP, etc.)
	Basic understanding of server and dial-up security issues
Control Systems	Basic device control issues
	Techniques for simplifying operator user interaction with a complicated system
	SOCCS, Creston, etc

APPENDIX B

ODOT Bi-Annual Budget Report Analysis

Description	Raw Material Cost	Labor Cost	Vehicle Cost	Driving Cost	Overhead Cost	Other
	[Yes = 1, No = 0]					
Bend Adm Admin	0	0	0	0	1	0
Field Operations	0	0	0	0	0	0
A/D Transp Manager	0	1	0	0	1	0
A/D Trans Devl/Suppt	0	1	0	0	0	0
TAD Project Delivery	0	1	0	0	0	0
Salem Section	1	1	1	1	0	0
Santiam Jct Section	1	1	1	1	0	0
Elec Crew, Reg 4	1	1	1	1	1	0
Bridge Crew, Dist 11	1	1	1	1	1	0
Bend Shop	1	1	0	0	0	0
Reg 2 Emergency Mgt	0	0	0	0	1	0
Elec Crew, Reg 2	1	1	1	1	0	0
Traffic Line, Reg 2	1	1	1	1	0	0
I T S Maint	1	1	1	1	0	0
Elec Crew-K Falls	1	1	1	1	0	0
Silver Lake Sec	1	1	1	1	0	0
Traffic Operations	1	1	1	1	0	0
Bend Section	1	1	1	1	0	0
Region 4 Adm	0	0	0	0	1	0
Signals	1	1	1	1	0	0
Lakeview Sect	1	1	1	1	0	0
Adel Section	1	1	1	1	0	0
Lake of Woods Sect	1	1	1	1	0	0
Maint Dist 11 Adm	0	0	0	0	1	0
Klamath Falls Sect	1	1	1	1	0	0
Sign Crew-K Falls	1	1	1	1	0	0
Fuel	1	0	1	1	0	0
R3 D8 Elec	1	1	1	1	0	0
Maint Dist 8 Adm	0	0	0	0	1	0
Ashland Sec	1	1	1	1	0	0
R3 D7 Elec	1	1	1	1	0	0
Maint Dist 7 Adm	0	0	0	0	1	0
Boswell Spring Sect	1	1	1	1	0	0
D7 N Douglas TMM	1	1	1	1	0	0
I T S Unit	1	1	1	1	1	0
Port Orford Sect	1	1	1	1	0	0
Hunter Creek Sect	1	1	1	1	0	0
D7 S Coast TMM	1	1	1	1	0	0
Radio Roseburg	1	1	1	1	0	0
Info Access Mgt	1	0	0	0	0	0
Bend AMM Admin	0	1	0	0	0	0
A/D TransDevl/Suppt	0	1	0	0	0	0
Radio Bend	1	1	1	1	0	0

APPENDIX C

Device Details for the Case Studies in California

Site	Communication			Power		Travel	
	On DOT Network?	Type of Communication	Communication with TMC	Power Source	Power Rating	Nearest Maint. Yard	Cost of Travel to Site
CCTV Cameras							
Snowman Hill	YES		Once per hour plus monitoring usage	Utility	120 Watts	Redding	1.5 hours each way
Hilt Sandhouse	YES		Once per hour plus monitoring usage	Utility	120 Watts	Redding	2.5 hours each way
Cedar Pass	YES		Once per hour plus monitoring usage	Utility	120 Watts	Redding	3.50 hours each way
Mount Hebron	YES		Once per hour plus monitoring usage	Utility	120 Watts	Redding	2.5 hours each way
Weed Airport	YES		Once per hour plus monitoring usage	Utility	120 Watts	Redding	1.5 hours each way
Red Bluff	YES		Once per hour plus monitoring usage	Utility	120 Watts	Redding	0.75 hours each way
RWIS							
Oregon Mountain Summit	NO	Dial-up off of Caltrans WAN	Once per 15 minutes	Utility		Redding	1.5 hours each way
Snowman Hill	NO	Dial-up off of Caltrans WAN	Once per 15 minutes	Utility		Redding	1.5 hours each way
Black Butte Summit	NO	Dial-up off of Caltrans WAN	Once per 15 minutes	Utility		Redding	1 hours each way
CMS/VMS							
5 N/B at Ream Rd.	YES		As needed	Utility		Redding	1 hours each way
5 S/B at Walters Road	YES		As needed	Utility		Redding	2 hours each way
5 N/B at Smith Road	YES		As needed	Utility		Redding	0.5 hours each way

Site	Communication			Power		Travel	
	On DOT Network?	Type of Communication	Communication with TMC	Power Source	Power Rating	Nearest Maint. Yard	Cost of Travel to Site
TOC/TMC							
District 2 RTMC	YES		N/A	Utility	50 KVA	Redding	On-site
HAR							
HAR at Hallelujah junction Ag. station	NO	Dial-up direct from TMC	As needed	Utility		Redding	3.5 hours each way
HAR at Four Corners	NO	Dial-up direct from TMC	As needed	Utility		Redding	1.25 hours each way
Radar CMS							
Sidehill Viaduct Radar CMS	NO	Dial-up direct from TMC	Continuous for speed detection and CMS, as needed for CCTV	Utility		Redding	0.5 hours each way
Lamoine Radar CMS	NO	Dial-up direct from TMC	Continuous for speed detection and CMS, as needed for CCTV	Utility		Redding	0.75 hours each way
Sims Radar CMS	NO	Dial-up direct from TMC	Continuous for speed detection and CMS, as needed for CCTV	Utility		Redding	1 hours each way

Device Details for the Case Studies in Oregon

Site	Communication			Power	Travel	
	On DOT Network?	Type of Communication	Communication with TMC	Power Source	Nearest Maint. Yard	Cost of Travel to Site
CCTV Cameras						
Paisley	YES		Once every 10 Min Long distance call	Commercial / UPS	Silver Lake Maint.	ITSSC $150-$200 Road Maintenace $35 $50
Quartz Mt.	NO	Phone Line/Modem	Once in 10 Min	Commercial /UPS	Lakeview	ITSSC $150-$200 Road Maintenace $35 $50
Warner Mt.	NO	Phone Line/Modem	10 Min	Commercial / UPS	Lakeview	ITSSC $150-$200 Road Maintenace $35 $50
Siskyous Smt.	NO	Phone Line/Modem	15 min	Commercial	Ashland	
Siskiyou Pass	YES		full motion video	Commercial	Ashland	
Wards Butte	NO	Phone Line/Modem	15 min	Commercial	Cottage Grove	
Port Orford	NO	Phone Line/Modem	15 min	Commercial	Port Orford	
Santiam Pass	NO	Microwave	Full motion	Commercial	Santiam Maintenance	ITSSC $50 Road Maint. $30
Willamette Pass	YES		Full Motion RC 5000 every 10 min	Commercial /UPS	Oakridge	ITSSC $100 Road Maint. $50
RWIS						
Oregon state route 58 RWIS	YES		Once per 15 minutes	Commercial	Oakridge	
Siskyou Summit	NO	Phone / Modem	Once per 15 minutes	Commercial	Ashland	
CMS/VMS						
Hilt	NO	Cellphone	On demand	Diesel / Solar		
Bailey Hill	NO	Cellphone	On demand	Diesel / Solar		
Medford	NO	Phone / Modem	Once a day for testing - future	Commercial		ITSSC $50
Klamath Falls	NO	Phone / Modem	Once a day for testing - future	Commercial		ITSSC $100
HAR						
Ashland HAR	NO	Cellular Phone	On demand	Solar / Battery		

APPENDIX D

<u>Preventive Maintenance Checklist used by Region 4 of Oregon DOT</u>

ODOT CCTV Maintenance Procedure (Cameras)
To be performed by ITSSC, TSSU or Contractor
Date: 7-24-03
Site Location: [redacted]

Technician(s): [redacted]

Please note inspections and any maintenance done or needed in the Logbook
Every 6 months:

OK	Needs Attention	N/A	Generic Site location observation
	✓		Ensure cabinet logbook is present
✓			Look for pest infestation
✓			Look and note vandalism or damage
	✓		Note vegetation growth around cabinet, eliminate if necessary
✓			Ensure cabinet is watertight
✓			Ensure duct seal is intact
✓			Ensure connections are tight
✓			Ensure wiring is neat and out of the way
✓			Ensure wiring is protected from sharp edges, kinks
		✓	Ensure door has a best lock, keyed ITS (Traffic Key)

OK	Needs Attention	N/A	Specific device observations
✓			Clean dome or window
✓			Examine housing for corrosion (fixed)
✓			Clean ground cabinet –brush and vacuum/blow
	✓		Replace filter
✓			Verify fan operation
✓			Verify thermostat operation
		✓	Verify PTZ operation (If applicable)
✓			Verify focus, field of view (fixed)

OK	Needs Attention	N/A	Annual Specific Items
✓			Update Inventory sheet
		✓	Ensure lowering device cable is secured to eyebolt in pole
		✓	Inspect, clean antennas (wireless solutions)
	✓		Replace de-humidifying crystals in camera housing (fixed)

Use back of sheet for additional details

ODOT CCTV Maintenance Procedure (Cameras)
To be performed by ITSSC, TSSU or Contractor

Date: 7-24-03

Site Location: [redacted]

Technician(s): [redacted]

Please note inspections and any maintenance done or needed in the Logbook

✓			Log into video server & verify user/pass/configuration
✓			Replace timer battery (power cycle timer)
✓			Check UPS and time in service
		✓	Test function of Power Pal.
			~~Replace batteries in timers~~

Problems found?
Vegetation at base of pole needs to be trimmed.
(Rose Bush)

Corrective Action taken?

Follow-up yet to be done?
Log book installed in cab.
Filter Replaced.

Use back of sheet for additional details

APPENDIX E

<u>Comprehensive Data Collection Form for Further Future Study</u>

- **Field Element Details**
  - Site ID
  - Equipment Details
    - Brand of the equipment
    - Age of the equipment
    - How is the equipment protected in the field, if any?
  - Communication and Power details
    - Type of communication source of the field element
    - Type of power source of the field element
- **Ticket No**
- **Problem Identification**
  - Is it scheduled preventive maintenance or reported maintenance activity?
    - Preventive Activity
    - Reported Problem
  - If reported, how the problem was identified?
    - Notified by public
    - Notified by other Caltrans personnel
    - Identified problems during regular checks of field elements
    - Identified through a self-diagnostic alarm
  - Who should be notified of the problem or scheduled maintenance next?
    - ITS Engineering and Support Group
    - Electrical Maintenance Group
  - Description of problem as notified
    - Partial failure
    - Complete Failure
  -

- **Start Time Line**
    - Time the problem was reported or scheduled (Hour: Minute)
    - Time the corresponding personnel were notified
- **Repair Activities**

Activity #	Activity Description	Start Time (HH:MM)	End Time (HH:MM)	Personnel Description	Travel (Yes / No)	If Traveled, Vehicle Type	If Traveled, Trip Length (HH:MM)	At the end of Activity, Is the System Functional? (Fully, Partially, Not at all)	Description of any replaced components and costs per each component
Start									
2									
3									
.									
.									
.									
End									

- **End Time Line**
    - Time the problem was completely fixed and the ticket was closed

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