# California-Oregon Advanced Transportation System

# Operations and Maintenance Technical Report

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for the

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## GLOSSARY OF ABBREVIATIONS

| | |
|---|---|
| AVC | Automatic Vehicle Classification |
| AVI | Automatic Vehicle Identification |
| AVL | Automatic Vehicle Location |
| CAD | Computer-Aided Dispatch |
| Caltrans | California Department of Transportation |
| CCTV | Closed-Circuit Television |
| CDPD | Cellular Digital Packet Data |
| CMS | Changeable Message Sign |
| COATS | California/Oregon Advanced Transportation Systems |
| CPA | Critical Program Area |
| DOT | Department of Transportation |
| DSAS | Downhill Speed Advisory System |
| GPS | Global Positioning System |
| HAR | Highway Advisory Radio |
| HazMat | Hazardous Materials |
| HTCRS | Highway Travel Conditions Reporting System |
| ITS | Intelligent Transportation Systems |
| LED | Light-Emitting Diode |
| O&M | Operations and Maintenance |
| ODOT | Oregon Department of Transportation |
| RWIS | Road and Weather Information System |
| SOC | Satellite Traffic Operations Center |
| TMC | Traffic Management Center |
| TOC | Transportation Operations Center |
| VMS | Variable Message Sign |
| VSLS | Variable Speed Limit System |
| WIM | Weigh-in-Motion |
| WTI | Western Transportation Institute |

# ABSTRACT

The California/Oregon Advanced Transportation System (COATS) project is a cooperative effort between transportation, law enforcement, tourism, emergency management, land management, commercial vehicle and other partners to address the transportation needs of the bi-state region through the use of intelligent transportation systems (ITS). One of the products of this effort will be the completion of an ITS strategic deployment plan, which will guide deployment of advanced technologies in the southern Oregon/northern California area in the future. Many ITS strategic plans typically focus on analyzing the financial and organizational needs associated with deployment, but give little consideration to the requirements for sustaining the ITS infrastructure. These considerations may be especially critical in rural areas, where it may be harder to dispatch maintenance staff to repair devices, and where deployments may be critical to ensure and promote the safety of the traveling public.

To address that concern, this report documents the operations and maintenance needs associated with the COATS ITS infrastructure. Because specific deployment quantities and locations have yet to be determined, the operations needs of ITS are discussed on a generic basis, understanding that power, communications and other needs are dependent upon the nature deployment. Maintenance needs are discussed more specifically for over fifty ITS devices, highlighting typical repair needs and the unique challenges that may be present with any given technology. The operations and maintenance needs are combined to present a rough estimate of the annual operations and maintenance costs on a per-device basis. Finally, institutional and organizational challenges that may impact operations and maintenance are discussed, creating a blueprint for further work in this area.

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# 1 INTRODUCTION

Intelligent transportation systems (ITS) have been typically considered as technologies appropriate only for urban areas where transportation problems cannot be readily resolved by increasing the capacity of the transportation system (such as through additional lanes of highway or additional fixed-guideway transit service). This understanding tends to miss the numerous opportunities that ITS can offer to improve transportation in rural environments as well, in areas such as safety, operations, maintenance, and traveler information.

One common problem in both urban and rural areas is that ITS technologies require not only an initial investment in design and construction, but continuing investment in operations and maintenance. In rural areas, this investment may represent a larger percentage of the device's initial capital cost, due to the challenges created by long distances between deployments and a lack of consistent utility and telecommunications infrastructure. For this reason, a particular emphasis should be placed on estimating the resources and issues associated with operations and maintenance of ITS technologies during the planning process, in order to ensure that these needs are adequately provided for in future resources. Unfortunately, such an emphasis is often neglected in ITS strategic planning efforts for rural areas.

The Northern California/Southern Oregon Advanced Transportation Systems (COATS) project covers a rural travel corridor for which such an operations and maintenance analysis is appropriate. This corridor consists primarily of areas of low population density with significant geographic, topographic and meteorological challenges. By addressing operations and maintenance considerations before deployment, the COATS project should help to enhance the longevity and usefulness of ITS technologies deployed in the corridor.

The purpose of this document is to provide guidance for operations and maintenance of ITS technologies in the COATS corridor. The document first considers the costs of operations of the ITS infrastructure. Operations costs need to be considered not only at the field device level, but also at the transportation management center, where field devices are managed and monitored. These costs will be discussed in Chapter 2. Chapter 3 focuses on maintenance, the other primary recurring cost associated with ITS technologies, including preventative or scheduled maintenance activities and repair or emergency maintenance activities. Based on the operation and maintenance considerations evaluated in Chapters 2 and 3, Chapter 4 presents approximate operations and maintenance cost estimates for each ITS technology on a per-device basis. Finally, Chapter 5 presents an overview of institutional and organizational issues that must be considered in evaluating future operations and maintenance requirements.

The findings of this document will serve two primary purposes. First, the per-device operations and maintenance cost estimates will be used as an input into the strategic plan document to provide a more realistic assessment of the true costs associated with each technology. Second, the organizational and institutional issues identified in Chapter 5 should help to provide an agenda for the COATS Steering Committee to work through in order to ensure that operations and maintenance considerations are not neglected as ITS devices are deployed.

# 2 OPERATIONAL REQUIREMENTS

There are several characteristics which tend to define the operational requirements of a given ITS deployment. This chapter will explore these common operational requirements, and how the costs of each may be estimated. This chapter is divided into three sections in order to better categorize costs: costs associated with the transportation management center[1] (TMC), costs associated with access to field devices, and costs associated with the field devices themselves.

## 2.1 Center Costs

The TMC is critical to successful utilization of ITS technologies to improve transportation in the region. In urban areas, there does not seem to be a clear relationship between the amount of investment into a TMC that is needed and the number and type of ITS devices which are deployed. This is more likely to be true in rural areas that tend to have less experience with TMCs and ITS in general. Therefore, this section will address only in broad terms the costs associated with the TMC.

### *2.1.1 Building*

The building serves as a physical point of integration where information about the transportation system is collected and distributed. The building serves the obvious functions of providing an indoor working environment for TMC staff as well as housing weather-sensitive equipment, such as computer servers.

Several factors will influence the operating costs of the TMC building, including:

- is the facility leased or owned,
- the size of the building,
- the costs of utilities,
- the range of functions intended to be performed in the TMC and the amount of space these functions would require, and
- the existence of space-sharing arrangements with other agencies (such as state police).

### *2.1.2 Staff*

The other critical on-going cost at the TMC will be the cost of staff located at the TMC who help to manage and use the ITS infrastructure. While it is possible to quantify the amount of maintenance staff required to support a given ITS infrastructure, it is very difficult to quantify the staffing levels required to sustain operations. In most urban deployments, the agency makes an initial assessment of what appropriate levels of staffing are, and then adjusts those later depending upon need. The number and skill set of employees housed at the TMC will depend

[1] TMC is used here to refer generically to either traffic management centers under California Department of Transportation (Caltrans) jurisdiction or to transportation operations centers under Oregon Department of Transportation (ODOT) jurisdiction.

significantly on the agency's vision for what the TMC's role is. Some potential tasks for TMC staff include:

- conducting traffic surveillance,
- detecting incidents,
- coordinating incident management efforts,
- monitoring road and weather conditions, and
- disseminating traffic information.

Staffing costs should include salaries and fringe benefits.

#### *2.1.3 Integration*

The TMC needs to be able to integrate information from sources that use different computer systems or data formats. Continuing effort will need to be spent on integration to ensure the seamless and accurate transmission of data across agencies. This cost will primarily be a one-time initial cost associated with computer programming, although on-going effort will be necessary as well.

#### *2.1.4 Office Support*

There are a myriad of other costs associated with the TMC, that may not be directly related to device deployment levels, such as overhead costs (to support accounting and payroll functions performed off-site) and office supplies.

### 2.2 Costs Between Center and Field

The second group of costs to consider is related with transmitting information or resources between the TMC and field devices.

#### *2.2.1 Vehicles*

As part of the ongoing operations and maintenance on an ITS infrastructure, vehicles will be necessary for performing some operational tasks (such as moving a portable variable message sign [VMS] from one location to another) as well as maintenance tasks. The size of a vehicle fleet based at the TMC depends upon the number of staff assigned to the TMC who have maintenance responsibilities. Vehicle costs will include costs for fuel as well as repair. Costs per vehicle are expected to vary widely depending upon duty cycles.

#### *2.2.2 Communications*

The cost of communications between the field device and the center depends upon the type of media used and in some cases on the amount of time spent transmitting information on the media. The media that should be used will depend upon the location of devices with respect to existing communications infrastructure, the amount of bandwidth required for successful operation, and topography. For wireline communications, it may be possible to have several field devices share the same communication link to the TMC.

## 2.3 Field Device Costs

The final portion of operating costs is the set of costs associated with the operation of field devices themselves. These costs are expected to be relatively constant for a specific device (unless it has highly seasonal usage), but will vary considerably from one device to another.

### *2.3.1 Power*

Most ITS devices will need to rely on a certain level of continuous power for successful operations. Three types of power are typically used for ITS field devices: electric, battery and solar.

- Electric. Generated from a variety of sources, electric power is transmitted through power lines to a field device. For field device locations where electric power is already available, this is generally the preferred method of power supply because of its reliability. The costs associated with using electric power include an initialization cost and monthly costs based on usage levels in kilowatt-hours (kWh).

- Battery. As opposed to having live lines connected to a power generation center, batteries may be used to provide power to devices. These are best used in applications where power usage is limited, since high power usage will expedite battery replacement. Rechargeable batteries may have some application for ITS technologies, but may not be ideal due to their tendency to lose charge over time independent of usage.

- Solar. Solar power is well suited to areas where electric service is not currently provided, power demand is not significant and daylight and cloud conditions are adequate to permit for recharging of solar batteries. Solar energy may be generated and stored locally at the device through the use of a solar array consisting of photovoltaic cells and a set of batteries to store power. Solar batteries lose their ability to store charge and must be replaced every few years. For applications where greater power is required, a diesel generator may be used in conjunction with solar energy to supply power when the batteries are exhausted. The use of diesel generators is recommended for applications where significant power is also required during overnight hours, such as a portable variable message sign warning of lane closures at a construction site.

### *2.3.2 Communications*

In addition to the costs of providing communication links between field devices and the center, there may be unique communication operating costs associated with each device depending upon the amount of bandwidth required to transmit data to or receive data from a specific field device. Some devices will communicate to the TMC only in the event that a specific event has occurred (i.e. a sensor detecting flooding has been tripped). Other devices will require continuous communications, such as a camera that transmits live images.

## 3 MAINTENANCE REQUIREMENTS

While there are some aspects to operational requirements that are common across different ITS technologies, maintenance requirements may vary considerably by device. Therefore, this chapter describes the devices that may be deployed in the COATS study corridor in order to improve the transportation system, along with their maintenance needs.

Maintenance needs were identified primarily through research done for the Oregon Department of Transportation (1). Devices were chosen for inclusion in this chapter based on consultation with the COATS Steering Committee. For the purposes of this document, devices are organized into one of seven critical program areas (CPA), as designated by the U.S. Department of Transportation's Advanced Rural Transportation Systems Strategic Plan (2). It should be understood that a particular device might address more than one CPA, as shown in Table 3-1.

### 3.1 Traveler Safety and Security

The first CPA focuses on technologies that are intended to improve traveler safety and security. Devices included in this section would be primarily roadside-based systems, rather than vehicle-based or driver-based systems. The purpose of these systems is to reduce the likelihood and severity of incidents, and to enhance the response capability of Department of Transportation (DOT) and emergency management personnel.

#### *3.1.1 Motorist-Aid Call Boxes*

The purpose of motorist-aid call boxes is to assist motorists in reporting incidents and breakdowns more quickly. These call boxes are typically environmentally sealed, heavy duty telephone handsets that are hard-wired directly to a dispatch center, so that they would not be used for non-emergency purposes. Most call boxes have neither telephone keypads nor automatic call classification procedures; rather the call box uses a voice message to dispatch appropriate assistance, as shown in Figure 3-1.

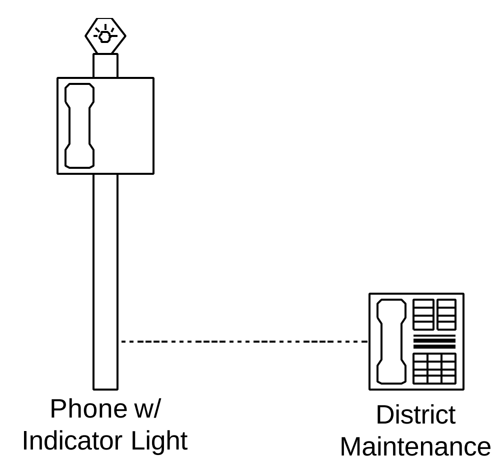


**Figure 3-1:** Motorist-Aid Call Boxes.

In general, call boxes need little day-to-day attention. The only maintenance activity recommended by manufacturers is to test them on a regular basis – perhaps monthly – to ensure that calls go through as expected (3).

#### *3.1.2 Cellular Call-In*

To expedite detection and reporting of incidents, many jurisdictions have worked with local cellular phone providers to provide a universal, cellular call-in telephone number. Calls to

| | Critical Program Area (CPA) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Device** | **Traveler Safety and Security** | **Emergency Services** | **Tourism and Traveler Information Services** | **Public Traveler/ Mobility Services** | **Infrastructure Operations and Maintenance** | **Fleet Operations and Maintenance** | **Commercial Vehicle Operations** | **Other** |
| Motorist-Aid Call Boxes | ✓ | × | | | | | | |
| Cellular Call-In | ✓ | × | | | | | | |
| Computer-Aided Dispatch | ✓ | × | | | | | | |
| Queue Detection System | ✓ | | | | | | | |
| Intersection Advance Warning Signing | ✓ | | | | | | | |
| Intersection-Based Incident Detection System | ✓ | × | | | | | | |
| Advanced Bicycle/Pedestrian Warning | ✓ | | | | | | | |
| Dynamic Warning Variable Message Signing | ✓ | | | | | | | |
| Variable Speed Limit Systems | ✓ | | | | | | | |
| Automated Anti-Icing System for Roads and Bridges | ✓ | | | | × | | | |
| Advance Warning Systems for Narrow Lane Widths | ✓ | | | | | | | |
| Automated Flood Warning | ✓ | | | | × | | | |
| Automated Gate Closure System | ✓ | | | | × | | | |
| Mayday Systems | ✓ | × | | | | | | |
| Traffic Signal Preemption for Emergency Vehicles | | ✓ | | | | | | |
| Incident Response Vehicles | | ✓ | | | | | | |
| Pre-planned Detour Routes | | ✓ | | | | | | |
| Alphanumeric Paging | | | ✓ | | | | | |
| 1-800 Number | × | | ✓ | | | | | |
| Television | × | | ✓ | | | | | |
| Internet | × | | ✓ | | | | | |
| Kiosks | × | | ✓ | | | | | |
| Changeable Message Signs | × | | ✓ | | | | | |
| Variable Message Signs | × | | ✓ | | | | | |
| Work Zone Delay Advisory System | × | | ✓ | | | | | |
| Highway Advisory Radio | × | | ✓ | | | | | |
| Automatic Vehicle Location | | | | ✓ | | | | |
| Transit Vehicle Routing/Scheduling Software and Vehicle Tracking | | | | ✓ | | | | |
| Automated Passenger Counting System | | | | ✓ | | | | |
| Smart Card System | | | | ✓ | | | | |
| On-Board Transit Safety Systems | × | × | | ✓ | | | | |
| Traffic Signal Priority for Transit | | | | ✓ | | | | |
| Automatic Vehicle Identification | | | | ✓ | | | | |
| Transit Traveler Information | | | × | ✓ | | | | |
| Parking Management and Information System | | | × | ✓ | | | | |
| Dynamic Ridesharing/Paratransit Service | | | | ✓ | | | | |
| Recreational Vehicle Park & Ride Lots with Surveillance | × | × | | ✓ | | | | |
| Automatic Traffic Recorders / Traffic Monitoring Station | | | | | ✓ | | | |
| Video Detectors | | | | | ✓ | | | |
| Closed-Circuit Television (CCTV) Surveillance | | | | | ✓ | | | |
| Road and Weather Information Systems | | | | | ✓ | | | |
| Travel Time Estimation | | | | | ✓ | | | |
| Highway Travel Conditions Reporting System | | | | | ✓ | | | |
| Regional Server/Coordination Software | | | | | ✓ | | | |
| Satellite Traffic Operations Center | | | | | ✓ | | | |
| Fleet Monitoring | | | | | | ✓ | | |
| Probe Vehicle Instrumentation | | | | | | ✓ | | |
| Electronic AVI Preclearance | | | | | | | ✓ | |
| Weigh-in-Motion | | | | | | | ✓ | |
| Downhill Speed Advisory System | | | | | | | ✓ | |
| Hazardous Materials Management | | × | | | | | ✓ | |
| Wireline Communications | × | × | × | × | × | × | × | ✓ |
| Wireless Communications | × | × | × | × | × | × | × | ✓ |
| Coordination Activities | × | × | × | × | × | × | × | ✓ |

Legend
- ✓ The CPA classification for this report
- × Other potential CPAs

**Table 3-1:** Devices by Critical Program Area.

this telephone number are automatically forwarded to the nearest emergency services provider. As market penetration increases, cellular phones are increasingly being used as the first report of incidents. Experience has shown that cellular telephone companies may be willing to absorb the cost of creating a call-in program as a public benefit (4).

Once the program is in place, ongoing costs associated with the program would be minimal. It is unlikely that a cellular call-in program would require additional resources at the dispatching center to respond to and track calls. Maintenance of the program would be focused primarily on roadside signage indicating the phone number, which could be included with sign maintenance programs at negligible additional cost. Maintenance of the cellular phones and cellular phone transmitters would be the responsibility of the cellular phone companies and subscribers.

### *3.1.3 Computer-Aided Dispatch*

Computer-aided dispatch (CAD) assists in dispatching police and emergency personnel to calls for help. It is primarily a database system that records the calls as they come in, giving the location and type of call, along with other pertinent information. As shown in Figure 3-2, workstations at TMCs can access the database as well.

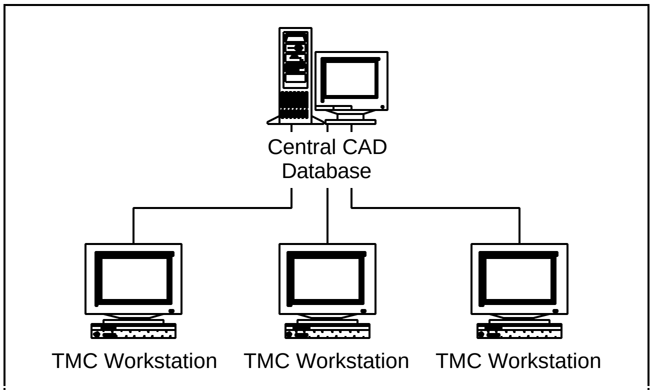


**Figure 3-2:** Computer-Aided Dispatch.

The system is designed primarily around the needs of the State Police, which supports the CAD mainframe and network connections to TMCs. TMCs may use information from the CAD system for a variety of incident management and response purposes, including dispatching incident response vehicles, providing information to motorists both pre-trip and en-route, and dispatching repair services for potential malfunctioning equipment.

TMCs typically have maintenance responsibility for equipment once it is inside the confines of the TMC building. This includes network connections and workstations.

### *3.1.4 Queue Detection System*

The purpose of a queue detection system is to alert motorists in limited visibility areas of upcoming queues in order to avoid rear-end collisions. The system works as depicted in Figure 3-3. Inductive loops installed in the road pavement are connected to a timer, which checks every few seconds to see whether vehicles are present over the loops. If a vehicle continues to be present over the loops, this will activate a flashing beacon sign well upstream of the loops. The sign is placed such that it provides a reasonable distance for the motorist to safely slow down and avoid getting into a rear-end collision.

Queue detection systems are typically localized and independent systems, not requiring communications with other ITS devices. Maintenance of these systems is fairly simple. In a

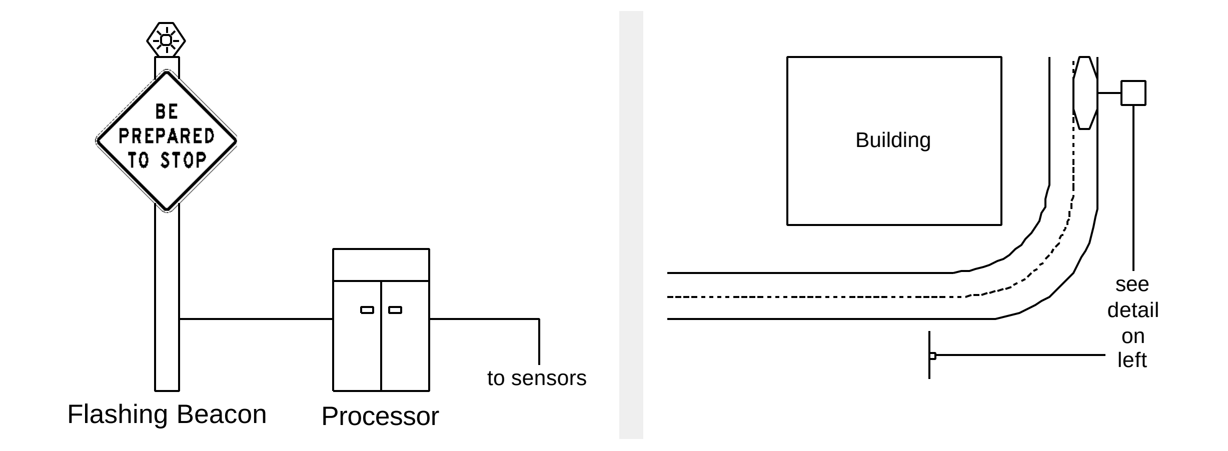


**Figure 3-3:** Queue Detection System.

system deployed in Oregon, a light-emitting diode (LED) at the timer cabinet indicates when the loop detector is occupied, providing quick diagnostics for the loop and local wiring. Annual testing should focus on ensuring that all connections from the loops to the flashing beacon are functioning acceptably, and that the timer is set at a reasonable delay.

### *3.1.5 Intersection Advance Warning Signing*

The purpose of this system is to detect the presence and speed of vehicles approaching an intersection from a minor roadway and warn travelers on the major roadway approach of a potential conflict through dynamic signing. These systems may be used in areas where speed zones decrease the traveling speed more than 20 mph or where rural conditions change to urban development. As shown in Figure 3-4, the system consists of detection equipment placed in each minor approach to a given intersection, a processor housed in a cabinet in the field, and flashing beacon signs facing each direction of traffic on the major roadway. The processor interprets data collected by the traffic detectors to determine when traffic on the major roadway may be

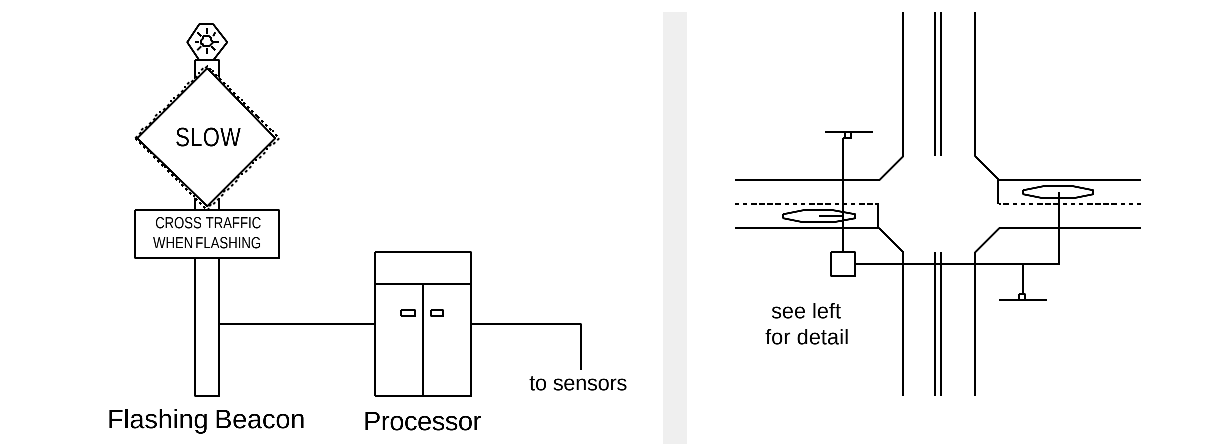


**Figure 3-4:** Intersection Advance-Warning Signing.

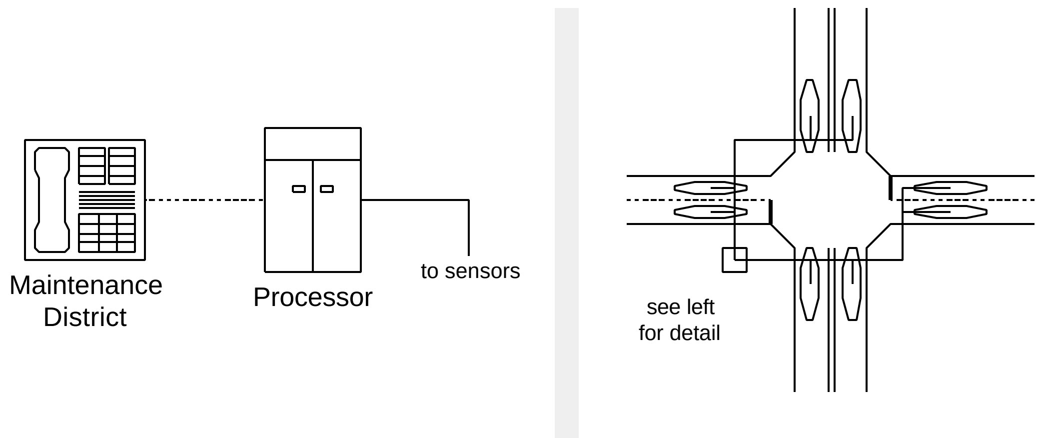


**Figure 3-5:** Intersection-Based Incident Detection System.

jeopardized by traffic activity on the minor roadway.

This system may be deployed independently of other systems, and would consequently require no telephone or other external communications capability. Maintenance needs would include regular testing and calibration of the detection equipment, and inspection of the wiring to ensure that the flashing warning will activate when appropriate.

### *3.1.6 Intersection-Based Incident Detection System*

The previous device is intended to reduce the likelihood of accidents at an intersection by reducing the potential for conflicting movements to occur simultaneously at intersections with poor visibility. If an incident does occur at a remote location, however, it is important to provide notification to emergency response services quickly. This can be done through the use of additional detectors on the major approaches, as shown in Figure 3-5. Having detectors on each of the approach and departure lanes allows for a significant change in traffic volume and/or speed to be detected. When the processor records this behavior as occurring, it may dial out to the maintenance district, which in turn may coordinate an appropriate response.

The maintenance needs of this system are slightly more complicated that those of the intersection advance warning system. The use of additional detectors will require extra time to maintain. The processor at the intersection will require some computational intelligence to be located in the field, which may necessitate additional maintenance activity. When functioning properly, this system will also require instant communication to the TMC. This communication link needs to be tested regularly, especially in areas where poor power quality may affect solid-state networking components, such as modems and routers.

### *3.1.7 Advanced Bicycle/Pedestrian Warning*

This device would consist of a push-button system that would activate a flashing beacon above a static sign that would indicate the presence of bicycles or pedestrians, as shown in

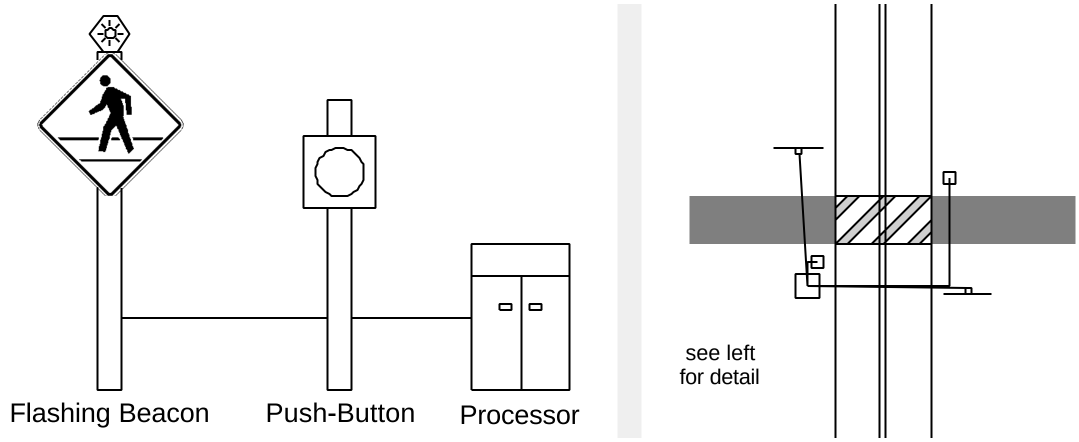


**Figure 3-6:** Advanced Pedestrian Warning System.

Figure 3-6. The sign would be located upstream of where the bicycle or pedestrian is crossing and would have an automatic shut-off after a period of time.

This system would have minimal operational and maintenance needs. Maintenance would consist primarily of regular system testing, although bulb replacement would also be expected.

### *3.1.8 Dynamic Warning Variable Message Signing*

Several systems use environmental sensors in combination with flashing beacons to provide warnings to motorists. Example applications of these systems include the following.

- Icy bridge detection systems. As shown in Figure 3-7, pavement sensors are used to measure temperature and moisture, as well as the presence of ice. When ice is detected, a field processor activates the flashing beacon sign to warn motorists.

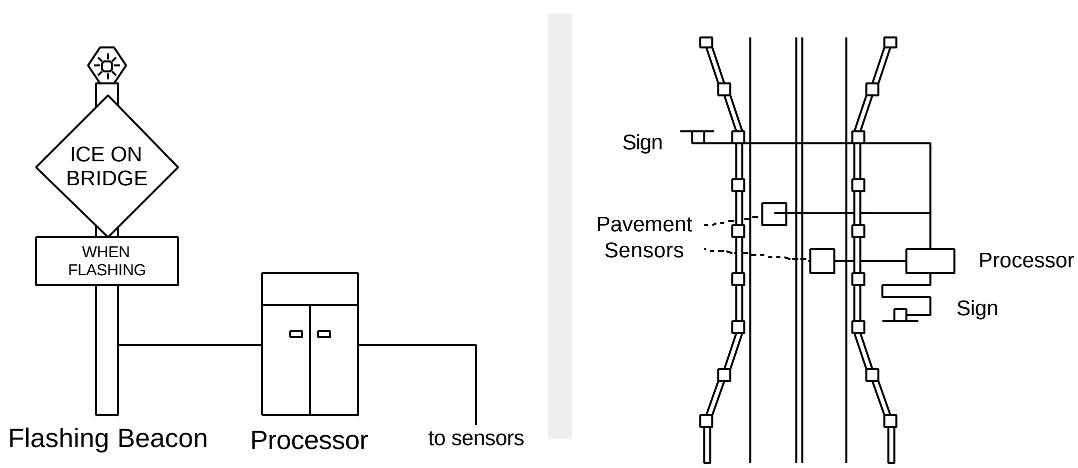


**Figure 3-7:** Icy Bridge Detection System.

- Automated visibility warning. In areas where fog, dust and similar conditions hinder visibility on a recurring basis, automated signing may be used to warn motorists. Figure 3-8 shows how this system may function. Visibility sensors communicate via wireline communications to a processor located upstream of the problem area (such as a valley), where a flashing warning beacon sign is activated. The visibility sensors may be installed independently or as part of a full road and weather information system (RWIS).

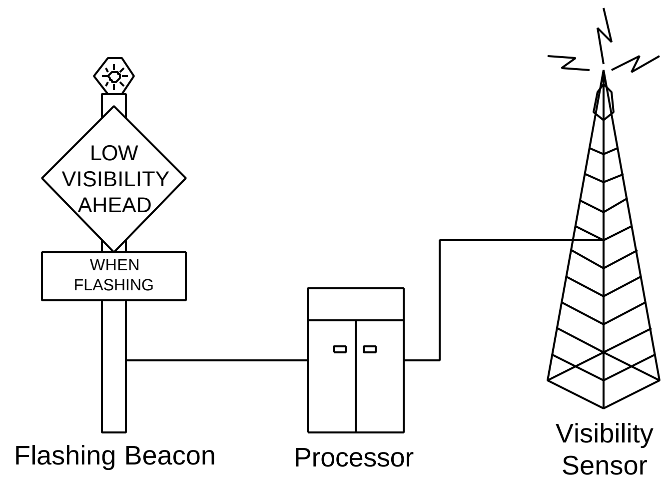


**Figure 3-8:** Automated Visibility Warning System.

- Oversize vehicle closure systems. These systems gather information about pavement temperature, wind speed and similar conditions, in order to identify conditions when oversize vehicles would have difficulty negotiating the road. An example of this system is shown in Figure 3-9, where the warning sign would be used to indicate when routes are closed to larger vehicles.

The critical maintenance component of these systems is to ensure that the field sensors are calibrated and functioning properly. Real-time communications outside of the field deployment would not be necessary unless the TMC decided to have real-time notification of when the

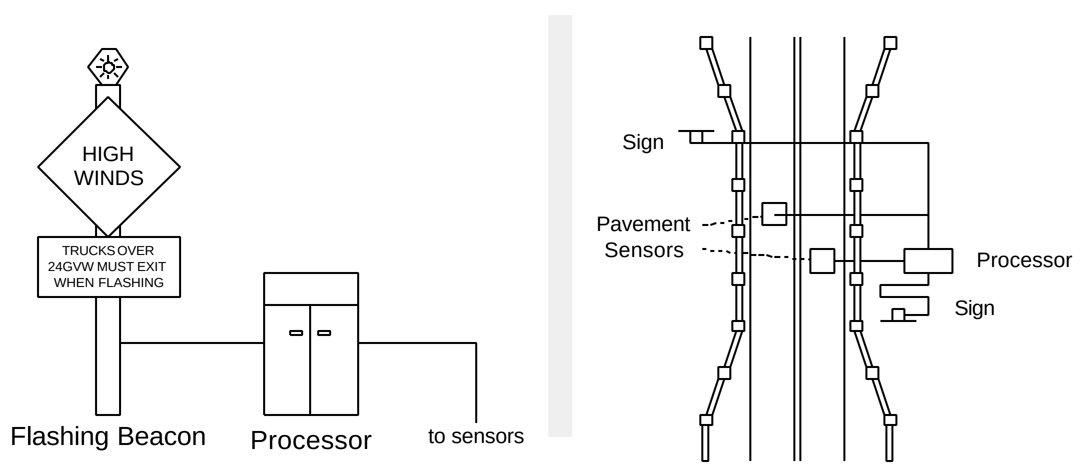


**Figure 3-9:** Oversize Vehicle Closure System.

system is activated.

### *3.1.9 Variable Speed Limit Systems*

Variable speed limit systems (VSLS) collect information from atmospheric and surface weather sensors by which posted speed limits may be adjusted on a real-time basis. These systems may help to reduce incidents at locations where they are frequently caused by vehicles driving faster than conditions warrant.

Figure 3-10 shows an example of how a VSLS may be set up. Various roadway surface sensors provide information about the presence of snow, ice or moisture. Other sensors may detect local visibility. Pairs of loop detectors embedded in the roadway surface determine vehicle speed. The information collected from these sensors is input into a field processor. The field processor may contain algorithms for estimating appropriate speed limits based on the results of sensor data (5). An alternative to using an automated algorithm is to provide sensor information to the TMC via a radio link. The TMC could then set speed limits based on experience and professional judgment. Once a reduced speed limit has been decided upon, the field processor activates a variable message sign, which indicates the revised speed limit (6).

Because of the liability exposure that may be associated with this system (7), timely preventative and repair maintenance activities are critical. Preventative maintenance activities, including routine testing of sensors and detectors, would be vital to minimizing liability exposure. Maintenance of these systems would consist first of calibrating and inspecting pavement sensors and traffic detectors on a regular basis. The pavement sensors are not prone to losing their calibration, but may be affected by lightning damage as well as skid marks. It is critical that the display component of the system also be adequately maintained[2].

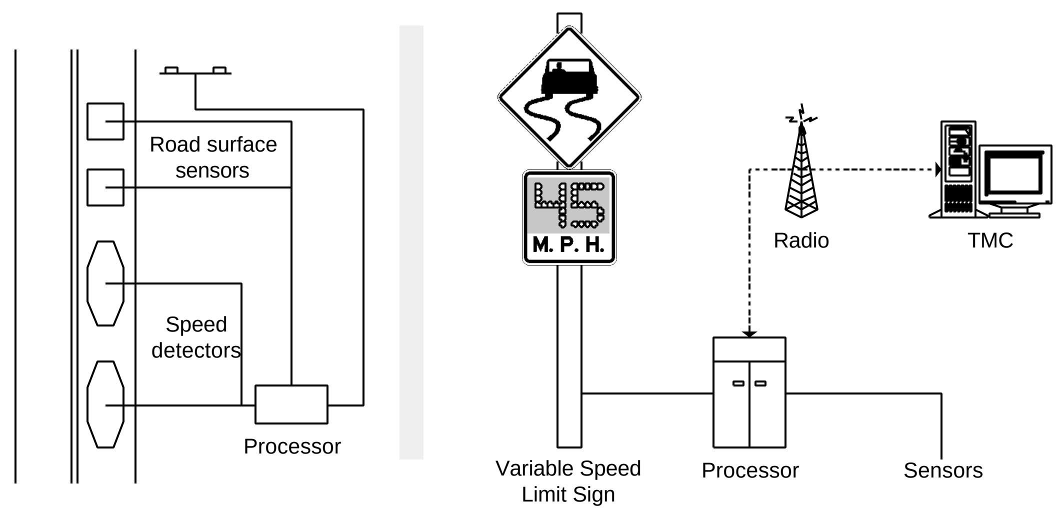


**Figure 3-10:** Variable Speed Limit System.

[2] See section 3.3.7 for detailed description of maintenance of variable message signs.

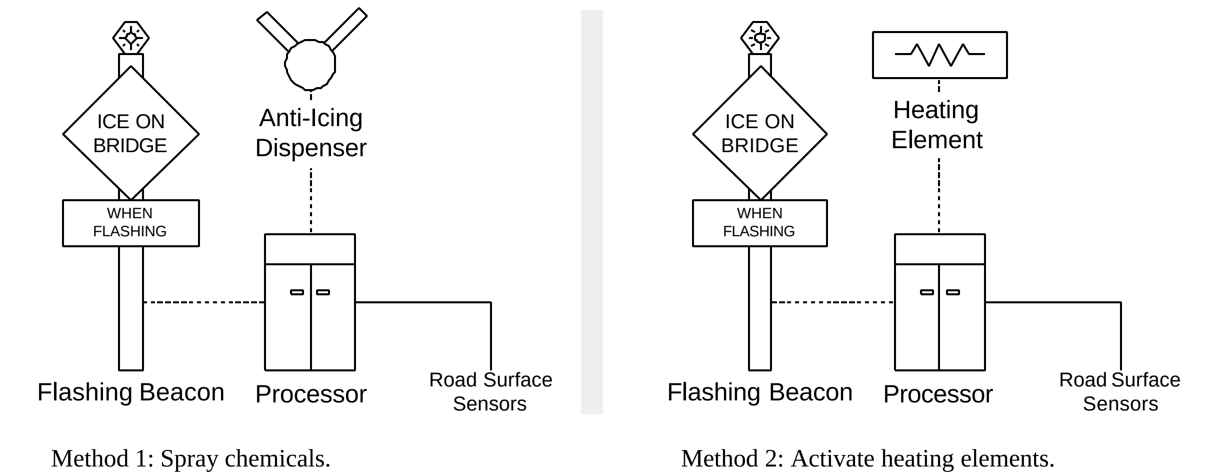


**Figure 3-11:** Automated Anti-Icing System.

### *3.1.10 Automated Anti-Icing System for Roads and Bridges*

Because ice tends to form and persist on bridges longer than on other portions of highway, preventing ice formation on bridges can help to significantly improve safety. Two types of automated systems, shown in Figure 3-11, may be used to help reduce the frequency and severity of icy conditions on roads and bridges. In both cases, road surface sensors are used to indicate when conditions are present under which ice is likely to form or has already formed. Once icy conditions are detected, one system sprays anti-icing chemicals over the roadway surface, while the other activates heating elements embedded in the roadway. The purpose of these systems is not to eliminate the need for snow removal, but to try to establish a consistent road surface quality between the bridge and adjacent portions of the roadway, thus enhancing safety (8).

The most significant maintenance concern for this system is ensuring that the road surface sensors are accurately detecting when icy conditions are present. The sensors are fairly hardy and require only minimal preventative maintenance. Sensor failure, due to lightning strikes and rubber from vehicle skidding, typically requires replacement of the sensor. The anti-icing dispenser should be inspected annually to ensure that the nozzles are not clogged by debris. The heating element method should need little maintenance once deployed.

The system may be improved so that it will contact local maintenance personnel when the sign has been activated. If this is done, regular testing should be done to ensure that communications between the field unit and the TMC are satisfactory.

### *3.1.11 Advance Warning Systems for Narrow Lane Widths*

In areas where there are narrow lane widths, traveler safety can be jeopardized when there is inadequate buffer distance from obstacles and limited sight distance. This is especially true when a vehicle passing in the opposite direction has a wide wheelbase, such as a commercial or recreational vehicle. This system would identify the vehicle size and speed through automatic

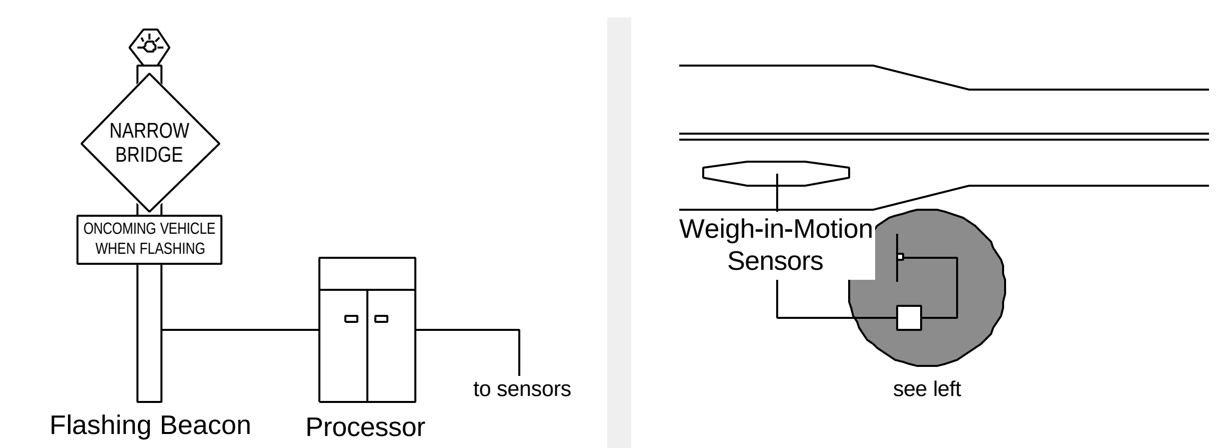


**Figure 3-12:** Advanced Warning System for Narrow Lane Widths.

vehicle classification sensors and loop detectors, and provide upstream warning to other travelers traveling in the opposite direction through a flashing beacon. This is shown in Figure 3-12.

In terms of preventative maintenance, the sensors will need occasional testing to ensure that they are classifying vehicle size accurately. Repair maintenance would most likely be necessary only when vehicles have damaged sensors or signage. Consequently, strategic location of these components so they are not easily damaged by traffic may be critical to minimizing the system's long-term maintenance requirements.

### *3.1.12 Automated Flood Warning*

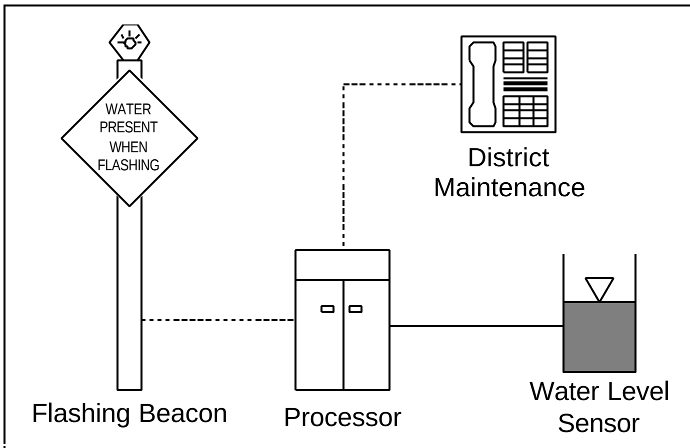


**Figure 3-13:** Automated Flood Warning.

The purpose of an automated flood warning system would be to remotely and automatically identify when water is present on the roadway. Figure 3-13 shows how this system might look. It would have two functions that would be concurrently executed once the sensors detect water: to notify maintenance crews with a prerecorded dial-up message from the field, and to inform motorists through the use of a sign with a flashing beacon.

Maintenance should focus on testing the components to ensure they are working acceptably. The water level sensor should be cleaned of debris annually to ensure that warnings regarding the presence of water on the roadway are accurate.

### *3.1.13 Automated Gate Closure System*

This system activates a barrier arm gate when severe conditions warrant, such as landslides or seismic activity. Figure 3-14 shows how this system may be set up. A seismic sensor measures tremor activity at a susceptible location, such as a bridge. When unacceptable activity is detected, a field processor lowers the gate arm to close the bridge to traffic, and simultaneously dispatches DOT and response personnel. This system aids in highway operation by alerting DOT officials so that qualified employees can confirm the structural integrity of bridges where a seismic event has occurred. It also improves traveler safety and security by closing the bridge to traffic during seismic events until the bridge has been inspected. Information from these systems may also be provided to pre-trip information systems such as kiosks to forewarn motorists of areas where roads are closed.

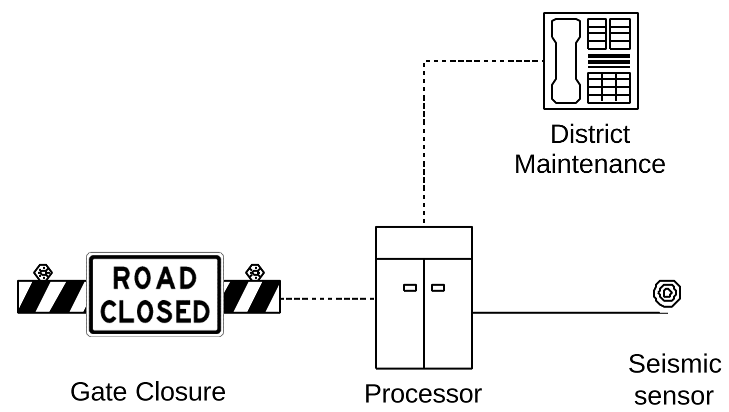

**Figure 3-14:** Automated Gate Closure System.

This system's maintenance needs are similar to the advance flood warning system. The sensor and field processor should be protected so that their operation will not be adversely affected by a seismic event. These systems will not need to regularly communicate to the TMC, although the TMC may wish to remotely diagnose these systems. These systems should be manually tested on a fairly regular basis to ensure that the gate arms activate properly.

### *3.1.14 Mayday Systems*

This system allows the user to initiate a request, either manually or automatically, for emergency assistance from the vehicle. Figure 3-15 shows how such a system may be set up. A simple vehicle-based after-market device or a cellular telephone with automatic vehicle location capabilities[3] would enable the driver to use this service. It is assumed that this system would direct requests to the

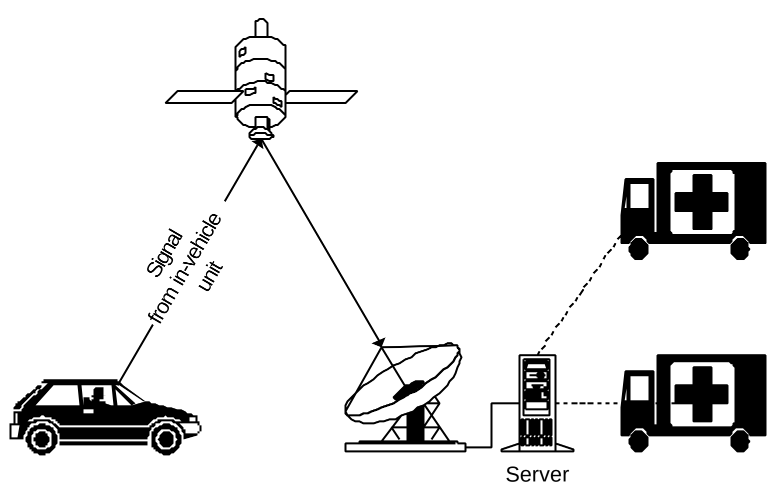

**Figure 3-15:** Mayday System.

[3] See section 3.4.1 for more information on automatic vehicle location systems.

nearest emergency response center, rather than to an intermediate center.

The maintenance needs of the in-vehicle units does not need to be considered, as their ownership extends beyond the scope of public agencies. The server would require global positioning system (GPS) software to be able to geo-locate the vehicle, and determine the emergency response facility that would have the shortest response time. After installation, the software should need little maintenance.

## 3.2 Emergency Services

In addition to improving traveler safety so that incidents may be minimized, intelligent transportation systems can also improve the operations of emergency services. This section describes some technologies that may work to that end, along with their maintenance needs.

### *3.2.1 Traffic Signal Preemption for Emergency Vehicles*

In order to expedite response to incidents, traffic signals may be equipped with sensors that alter the intersection's signal timing to allow an emergency vehicle to pass through. The equipment interfaces with conventional traffic signal controllers as shown in Figure 3-16. A signal-emitting device is located within the emergency vehicle, and a sensor is placed on the signal mast. When the sensor detects an emergency vehicle is approaching, it communicates to the controller to stop the current light cycle in order to present a green indication to the emergency vehicle. The signal timing pattern will resume after some pre-determined time interval elapses.

This device adds only negligibly to the existing operational and maintenance needs of a traffic signal. The sensor and in-vehicle device should be tested periodically to ensure they are working properly. These systems are not connected to either other ITS systems or the TMC.

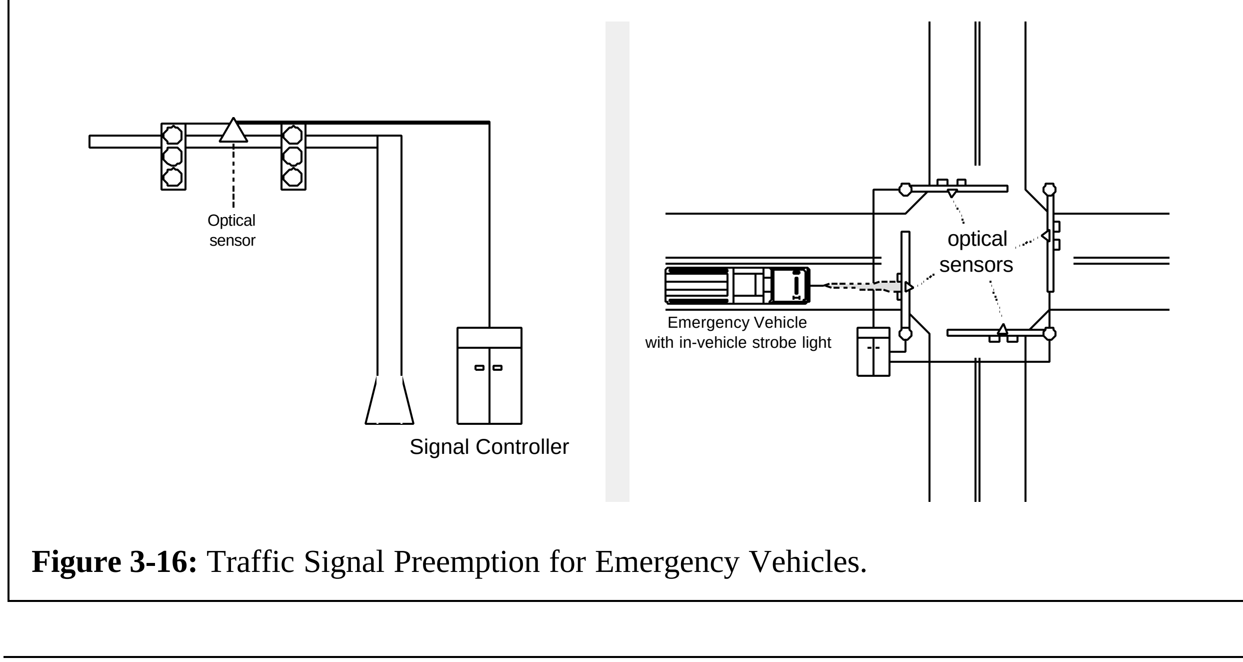


**Figure 3-16:** Traffic Signal Preemption for Emergency Vehicles.

### *3.2.2 Incident Response Vehicles*

One effective tool in reducing both the safety hazard and time delay caused by incidents or stalled vehicles is to have an incident response vehicle ready to assist in clearing disabled vehicles from the roadway. Typically, response vehicles, such as shown in Figure 3-17, are equipped with several advanced technologies, including:


**Figure 3-17:** Incident Response Vehicle in Action.

- an automatic vehicle location (AVL) in-vehicle unit, to provide location information to the dispatching center;
- a laptop computer, for recording any pertinent information about response calls;
- cellular phone communications and radio communications, to aid in soliciting help from others; and
- on-board VMS, to provide en-route warnings to other motorists.

Maintenance for the vehicles themselves is normally covered under traditional fleet maintenance activities. The ITS devices on-board each incident response vehicle have unique maintenance activities. For truck-mounted VMS, maintenance needs are typically relatively low, focusing on sign cleaning[4]. The vehicles' laptop computers typically are used for incidental activities, such as assisting in record keeping or in providing additional messages to the on-board VMS beyond the messages which are already programmed (9). Consequently, maintenance needs for the laptop computers tend to be fairly low. The in-vehicle AVL unit will require limited maintenance[5]. The maintenance of the communications components will be fairly negligible, since it will generally be less expensive to replace than to repair.

To preserve the effectiveness of the incident response vehicles, their downtime must be minimized. To help in this effort, regular inspection and testing is recommended to ensure that the VMS, AVL and on-board communications systems are functioning effectively.

[4] See section 3.3.7 for more information on maintenance of portable variable message signs (VMS).
[5] See section 3.4.1 for more information on maintenance of automatic vehicle location (AVL) technology.

### *3.2.3 Pre-planned Detour Routes*

One effective tool for incident management is to have a set of pre-planned detour routes on hand. These routes would provide alternative routes for travelers in the event that an incident or natural disaster is blocking a key roadway segment. Identification of these routes would be a key component of a regionwide incident management plan. Pre-planned detour routes may be integrated with other ITS deployments, such as variable message signs (see Figure 3-18) or highway advisory radio, in order to provide motorists en-route information about recommended detours.

For these routes to be useful, a regular review process is essential to ensure that recommended routes are appropriate in light of travel demand patterns, construction activity, and other factors. If there is any automatic implementation of these routes through roadside information dissemination, the linkages between the detour route database, route selection and information dissemination need to be regularly checked.

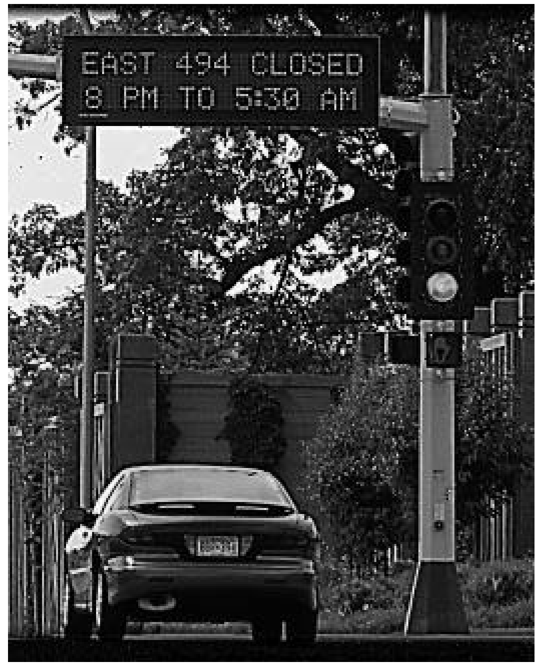


**Figure 3-18:** Example of Pre-Planned Detour Route Signage.
(Source: 10)

## 3.3 Tourism and Traveler Information Services

Intelligent transportation systems can help to improve pre-trip and en-route traveler information as well, not only providing information about road and weather conditions but also about tourist opportunities. This section reviews some of these technologies.

### *3.3.1 Alphanumeric Paging*

In order to improve dissemination of information about incidents or weather conditions which may affect traffic, a TMC may send messages to pagers stationed with local commercial media, including television and radio. A typical page might include information about incident location, number of lanes blocked, anticipated delay, and recommended detour routes.

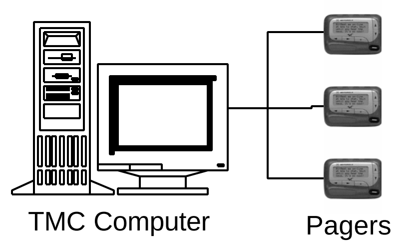


**Figure 3-19:** Alphanumeric Paging.

As Figure 3-19 shows, this system is functionally simple. Once a software interface is installed at the TMC, an operator may enter information into the computer. The software program will then send pages to each number on a pre-determined list with the indicated message.

The primary operational component of this system from an agency perspective would be the time spent in data entry, so operational needs should be minimal. A commercial paging service can be responsible for ensuring the integrity of paging units and the supporting communications infrastructure, so maintenance needs for this system should also be negligible.

### *3.3.2 1-800 Number*

One common way of disseminating information to travelers is through the use of an 800-number. An 800-number can be operated on a statewide basis and updated to reflect the latest highway and weather conditions. Both Oregon and California have systems in place which allow travelers to listen to road conditions for specific travel routes.

Typically, these systems rely on a group of integrated servers with dozens of telephone lines, as shown in Figure 3-20. One server typically houses the information on current travel conditions. This server is responsible for receiving data updates, sending data packet updates onto the other servers, and receiving and directing telephone callers.

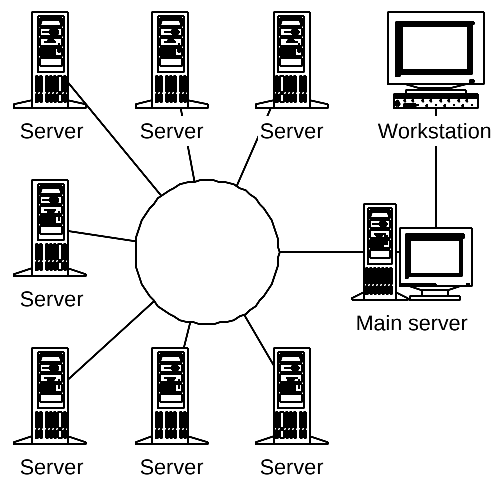


**Figure 3-20:** 800-Number Information.

Initially, this system may require significant human intervention in order to manually update conditions as they change. However, text-to-voice conversion tools and improved systematic computerized tracking of incidents and road conditions may reduce this operational requirement. The system will require maintenance for ensuring the integrity of the servers, and upgrading and repairing the software.

### *3.3.3 Television*

Local and cable television channels can be used to communicate valuable road condition, weather and traffic information to a large audience using regional interest and transportation-related programming during emergencies. Two primary alternatives exist for this system. First, the transportation agency may provide commercial stations access to feeds from remote camera locations which the stations can incorporate into their news broadcasts. Because of the expense in receiving live feed from rural locations[6], this is not highly applicable to the COATS corridor.

[6] See section 3.5.3 for more information on closed-circuit television (CCTV) cameras.

Alternatively, dedicated television channels may be set up and run by the agency. These channels can also be used to disseminate tourist-related information. Emergency messages may be transmitted using FM side-band and shown on the bottom of the television screen.

In order to minimize the cost of this system, traveler information on television is usually assembled and programmed automatically. For example, TrafficTV in Seattle repeats a regular sequence of video images from four different DOT roadside cameras along with current satellite weather maps. Images are displayed with color-coded maps showing travel speed, which are generated automatically based on data collected from the field. No spoken messages or special traffic bulletins are displayed, which reduces the amount of human interaction required (11). Primary maintenance activities consist of regular monitoring and diagnostics on the computers involved in generating the picture before it is broadcast.

### *3.3.4 Internet*

Another media that may be used to provide traveler information is the Internet. The Oregon Department of Transportation (ODOT) recently unveiled a Web site called TripCheck. This service integrates camera images, weather information, and information about expected delays resulting from incidents (12). This site was developed and is maintained by ODOT.

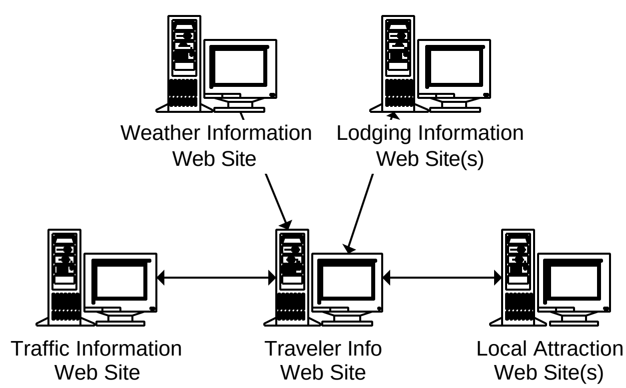


**Figure 3-21:** Internet Travel Information.

This "device" does not need to be restricted to traffic information. As shown in Figure 3-21, Web sites may also contain links allowing users to perform many tasks ranging from making lodging reservations to obtaining information on local attractions.

Once a Web site has been developed, maintenance consists primarily of making sure that the Web server is functioning properly and that all information and links are current and functional. An organization may devote as much time as it chooses to improving the Web site design by making it more user-friendly and providing additional links to users. It seems that successful Web sites usually have some staff member devoting a regular portion of their time to upkeep and improvement of the site.

### *3.3.5 Kiosks*

Kiosks are another form of information dissemination. These are stand-alone cabinets with a computer that would interactively provide users with information upon request. They are typically located at areas where large numbers of people are making travel-related decisions, such as major employers, shopping centers, highway rest areas, truck stops, airports, and transit transfer centers.

Older generations of kiosks relied on laserdisc technology to store information; the Internet is now preferred due to its flexibility as well as the high cost of continually updating laserdiscs with new information. Most kiosks now extract information either on a real-time basis as users request information, or on a semi-real-time basis where the most recent information is downloaded on a nightly or weekly basis.

As shown in Figure 3-22, a kiosk is very similar to a basic desktop computer. A monitor is provided for access by customers. The machine will typically use a touchscreen monitor to serve as the user interface, although a keyboard may be used instead. The CPU is contained in a cabinet, as well as a thermal printer to print information as requested. The cabinet is hooked up to a phone jack, as well as a power source, in order to keep the kiosk active and current.

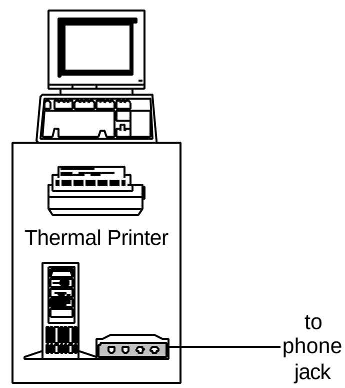


**Figure 3-22:** Kiosk.

In the experience of one agency with a large deployment of kiosks, the most significant maintenance issues with their kiosks have been printer problems, network breakdowns, and software failures (13). Because kiosks are often located in areas that are not environmentally controlled, the printers often fail due to "bad air" – i.e. poor temperature or humidity control. In addition, printers need regular maintenance to ensure that the paper supply and print quality are adequate. Network breakdowns often occur because kiosks are moved at their host sites causing physical damage to network connections. Another major source of network failures is the occasional reliance on local networks that are out of an agency's jurisdiction, which may have firewalls preventing regular updating of the kiosk information.

Maintenance needs for a kiosk system would be focused on the computer. Typical preventative maintenance activities would include cleaning the computer screen and testing to ensure that the user interfaces (keyboard, touch-screen, etc.) function acceptably. Due to the visibility of kiosks, preventative maintenance should be performed very frequently, perhaps even monthly. Because of the frequency of maintenance and the limited technical expertise it requires, site hosts may be the best qualified to perform this type of maintenance. Repair maintenance may be required for the reasons cited earlier as well as vandalism.

The challenge of providing maintenance support to high-visibility and geographically scattered kiosks may be eased through the use of public-private partnerships. Some site hosts may be willing to pay for the capital, operations and maintenance costs of kiosks to serve as a host site. In addition, advertising on kiosk cabinets could be used in exchange for companies paying for on-site maintenance through a contractor.

### *3.3.6 Changeable Message Signs*

Changeable message signs (CMS) are roadside devices that have the capability of displaying one of a limited number of fixed messages. The technology employed in CMS may vary considerably, as shown in Figure 3-23, from a radio-activated, fold-out sign that opens on a hinge, to a rotating drum sign that displays a couple of different messages. For this document, CMS are defined to include only those signs that must be manually activated.

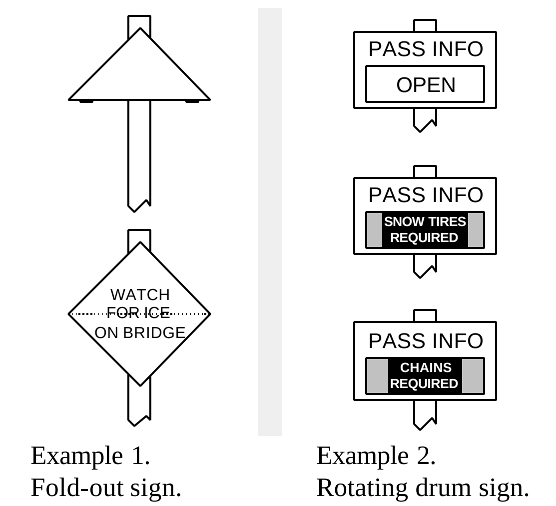


**Figure 3-23:** Examples of Changeable Message Signs.

CMS have applications in areas where changing weather conditions may affect vehicle traffic. These signs may provide warning about icy locations, instruct motorists to chain up, or direct oversize vehicles to exit the roadway. CMS may also be used in areas where lane closures due to incidents are common, such as in some tunnel locations.

Maintenance for CMS focuses on two elements: the communication of the signal to the sign, and the operation of the sign itself. For communications to the sign, a combination of wireline and wireless communications is used, depending upon the location, with minimal preventative maintenance needs. The sign display's maintenance needs may vary considerably, based on the age of the equipment and degree of environmental exposure.

### *3.3.7 Variable Message Signs*

Unlike CMS, variable message signs (VMS) are not constrained to a fixed number of messages. Messages may be programmed to describe information specific to existing conditions, including incident location, detour information, weather-related closures, and other types of information.

A typical system architecture schematic for VMS is shown in Figure 3-24. Messages for the VMS are created at a TMC and are relayed by modem connection to a controller in the VMS. The controller interprets the message and sends signals to the sign pixels to change to reflect the new message.

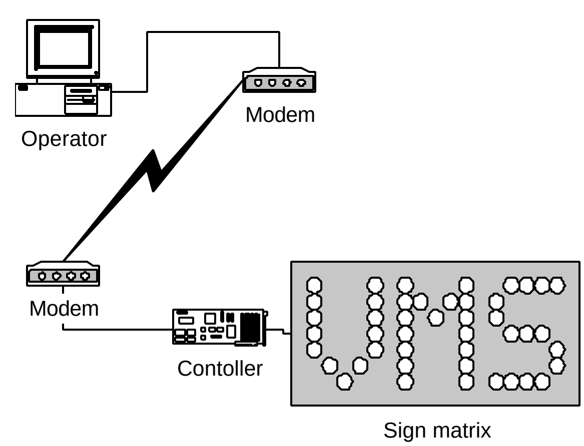


**Figure 3-24:** Variable Message Sign.

There are three basic VMS technologies that may be used individually, or in combination to achieve more optimal displays (14, 15). These base technologies include the following.

- Flip disk. This technology uses a matrix of disks with one side black and one side covered with bright, reflective material. Each disk is electromechanically flipped based on input from the controller. Power needs are minimal for this system, as motion is limited to times when the disks are flipped. Maintenance needs are considerable, however, as disks need frequent cleaning and may get stuck.

- Light-emitting diode (LED). Four bright LEDs are joined to create one cluster that represents a pixel on the sign matrix. The controller provides power to different pixels based on input from the controller. Power needs for LEDs are minimal, as are maintenance needs since LEDs are rated for 100,000 hours of continuous operation at the rated voltage (14, 16).

- Fiber optic. This technology has two light sources and bundles of glass fibers that serve as the pixels in the matrix. Shutters in front of each pixel open and close in order to display messages. The lamps used in fiber optic displays typically have about 6,000 hours of rated life (17, 18).

Besides the display element, maintenance may be necessary for the sign housing, controller, power supply, and communications equipment. It is recommended that filters be cleaned between two and four times per year (16, 18, 19), and that other components be inspected annually.

In addition to different types of sign displays, there are two types of VMS deployments: permanent and portable.

- Permanent VMS. Permanent VMS are normally mounted on bridges and overpasses or on overhead trusses. Smaller permanent VMS may also be installed on the roadside. These signs have significant visibility; hence, prompt maintenance is important from a public relations perspective. Experience has shown that maintenance needs vary not only based on the display technology, but also on the basis of the particular manufacturer, and the degree of exposure to precipitation and vandalism. From an operations perspective, different manufacturers usually require different software to program their signs, so standardization of vendors would tend to streamline operations.

- Portable VMS. Portable VMS are normally mounted on trailers or trucks, and are transported to locations on demand. They may be deployed due to temporary detours, incidents, construction information, or similar situations. Because of their mobility, portable VMS typically need to supply their own power. Solar-powered signs using a battery back-up are a fairly common power mechanism, although diesel power is also used. Maintenance needs for the display component of portable VMS are slightly less than for permanent VMS because portable VMS are typically smaller with easier access, and the sign may be transported to a technician as necessary. Field experience has found that there are significant, frequent problems portable VMS may experience during transport, including damage to cellular modems and sticking of flip disks.

### *3.3.8 Work Zone Delay Advisory System*

The work zone delay advisory system provides travelers with an active indication that there are delays within a work zone. Several different technologies may be used for this.

The simplest system is a static sign with flashers that can be manually activated when there are delays. This system would require minimal maintenance, especially for the majority of construction projects that are completed within one construction season. For operations, the system would need to have a reliable power supply that would be effective whenever lane closures and/or construction activities are in progress. Solar power may be adequate for this task, unless lane closures are left in effect for overnight hours, in which case other power sources would be recommended. Testing this system would be simple.

The second level system uses speed sensors to determine approximate delay through the work zone and variable message signs to transmit information to the travelers, as shown in Figure 3-25. This system would require more sophisticated intelligence in the field, perhaps a simple microcomputer, to estimate travel time delays based on data collected through traffic detectors. The processor would require regular inspection and reliable power, but should need little in terms of repair maintenance. The variable message sign would need regular maintenance to ensure that the sign is able to change messages as conditions warrant. No communications would be necessary for this system, except between the field sensors and the processor.

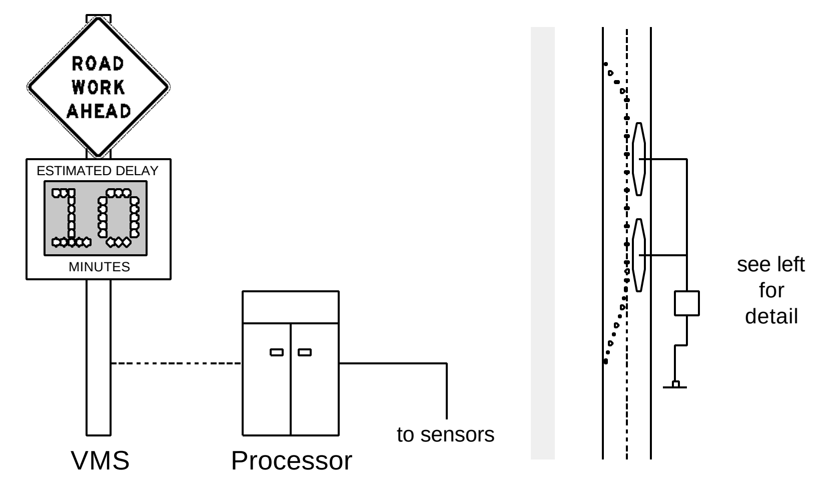


**Figure 3-25:** Work Zone Delay Advisory System – Alternative 2.

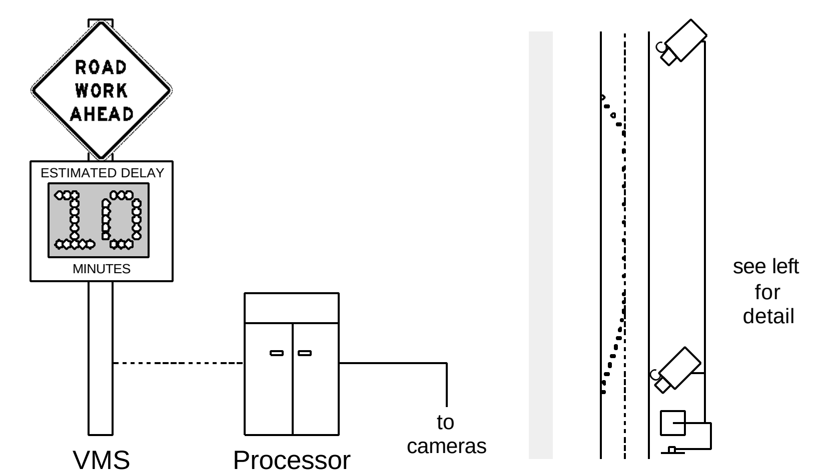


**Figure 3-26:** Work Zone Delay Advisory System – Alternative 3.

A third type of system based on this concept is shown in Figure 3-26, where license plate matching[7] is used to record travel times between two points at the end of the construction zone. The travel time is calculated against a free-flow travel time, and the resulting delay is depicted on the variable message sign. Other methods of travel time measurement, such as vehicle probes, may be used instead of license plate recognition. The maintenance needs of this system would be similar to the second method, except that the license plate readers may require more sophisticated maintenance skills than simple vehicle detectors.

### *3.3.9 Highway Advisory Radio*

Highway advisory radio (HAR) is a localized radio broadcast system designed to provide motorists with location-specific information, such as current traffic conditions, construction information, weather advisories, or directions to major tourist destinations. The basic system architecture for HAR is shown in Figure 3-27. A low-powered AM transmitter is connected to a voice storage unit via leased telephone lines. The voice storage unit may be updated via telephone in order to reflect changes in conditions. Because HAR systems are typically localized to a three to six mile radius, roadside signage and/or beacons are used to indicate where HAR systems are present and when they are in operation.

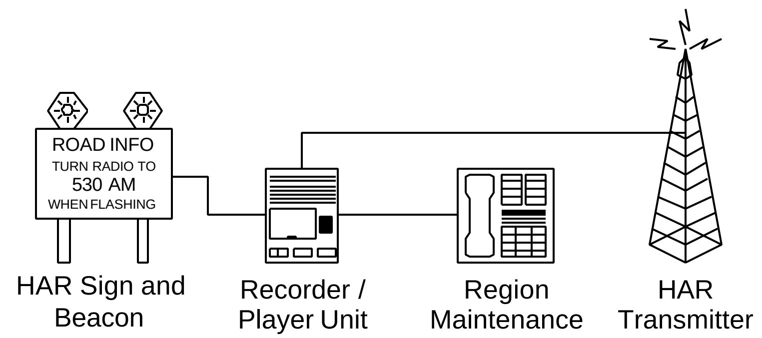


**Figure 3-27:** Highway Advisory Radio.

Maintenance of HAR systems has become less time-consuming over the years. The use of solid-state electronics reduces periodic maintenance needs such as replacing magnetic tape. Annual periodic maintenance activities include periodically checking the HAR sign for interference from vegetation, new construction, signs or other antennae, and regularly checking the range of the signal and the power supply (20). Operational needs of HAR may vary, depending upon whether the system is updated automatically (similar to the 800-number system described earlier) or manually.

## 3.4 Public Traveler/Mobility Services

Intelligent transportation systems can assist services that enhance mobility to members of the traveling public who either are unable to drive or choose not to drive. These technologies can help service operators to improve efficiency and service quality, and can help potential users by improving transit information and reliability. This section highlights a few technologies that have been identified as having potential applicability to the COATS corridor.

[7] License plate recognition is described in greater detail in section 3.5.5.

### *3.4.1 Automatic Vehicle Location*

Automatic vehicle location (AVL) is a technology by which information about a vehicle's location may be transmitted automatically to a remote destination. For transit applications, this can assist in improving route reliability, enhancing dispatching capability and efficiency, providing quicker response to service disruptions and mechanical problems, and providing input to passenger information systems. AVL was also mentioned in conjunction with incident response vehicles in section 3.2.2. One or more of the following four location technologies may be used (21).

- Dead reckoning. The vehicle starts from a known point and, using its odometer and compass directions, derives its location. This technology requires frequent calibration of the vehicle's location against known reference points.

- Ground-based radio. This relies on transmitting and receiving towers to triangulate vehicle position. This system has difficulty in areas of changing topography (such as rural canyons or urban landscapes).

- Signpost and odometer. Radio beacons are installed on routes to send signals to the vehicle, which combines with odometer readings to locate the vehicle. This would not work well in paratransit applications where fixed routes are not as frequently used.

- GPS. This relies on a network of orbiting satellites to position vehicles through triangulation. For this technology to be implemented, vehicles are equipped with an in-vehicle unit that integrates a GPS receiver, a modem, a display unit and a simple keypad. The in-vehicle unit, in turn, may be connected with sensors on the vehicle that may characterize the vehicle's activity, such as passenger boarding and alighting. A computer receiver records vehicle locations and then transmits this information to the appropriate operator. This is shown in Figure 3-28.

It is assumed that GPS would be used as the foundation of an AVL system in a rural

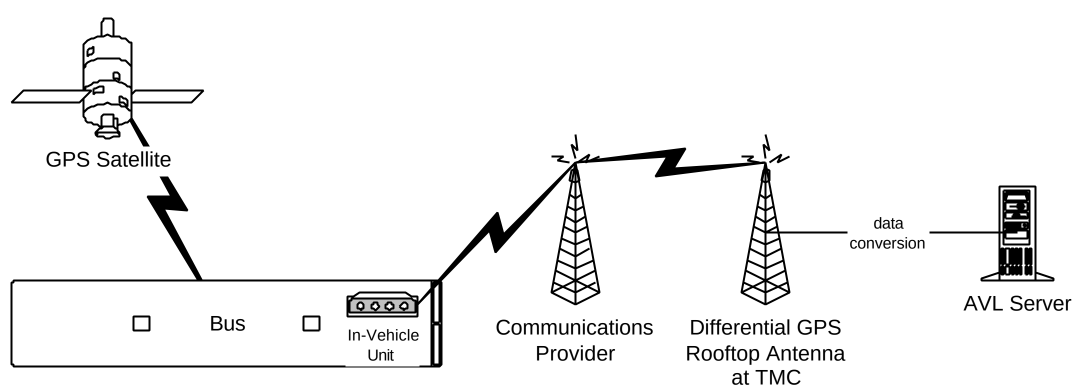


**Figure 3-28:** Automatic Vehicle Location.

environment.

Operations and maintenance of the satellite communications system are usually outside the responsibility of the customer. For the in-vehicle units, one vendor has said that they typically require negligible maintenance except where they may interact with on-board sensor systems, which are typically not provided by the vendor (22). The particular ground-based communications system will depend on local infrastructure availability. Cellular digital packet data (CDPD) and low-band radio are potential alternatives. The operations and maintenance of these systems will depend on the arrangements selected for a particular geographical region.

### *3.4.2 Transit Vehicle Routing/Scheduling Software and Vehicle Tracking*

Once an AVL system is in place, software may be added to assist in routing, scheduling and tracking of vehicles. This software could help to develop and maintain vehicle itineraries, monitor fuel usage and other vehicle operation characteristics, and permit multiple agencies to coordinate efforts to more efficiently utilize vehicles. To fully exploit this capability, the software needs to be seamlessly integrated with the AVL system. In addition, if activities are being coordinated across multiple agencies, it is essential to have real-time communication capability between various centers.

The operations and maintenance needs of this "device" are minimal provided that the software is not developed using in-house support. The software should be capable of working with the AVL system without additional operational or maintenance support.

### *3.4.3 Automated Passenger Counting System*

The automated passenger counting system allows for increased management of passenger counting and fare payment. The system may be used for obtaining more accurate ridership information. It consists of three components, described as follows (21).

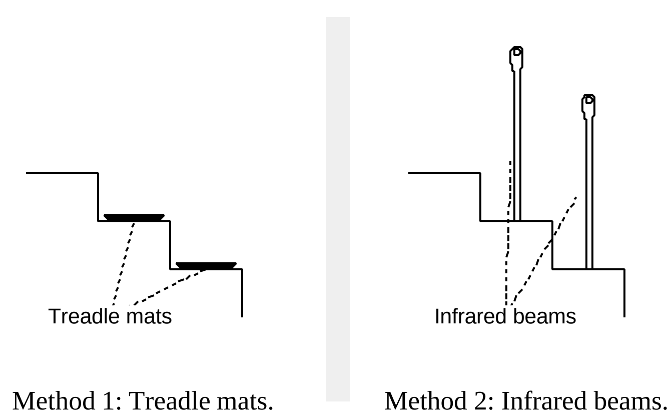


**Figure 3-29:** Automated Passenger Counters.

- Counter. This component counts passengers as they board and alight and is capable of distinguishing between boardings and alightings. Two alternative technologies are shown in Figure 3-29. The first alternative is to use treadle mats placed on at least two of the steps. The system can determine whether a passenger is boarding or alighting based on the order in which the mats are depressed. This system is subject to hazards such as water damage and fatigue from usage. A second alternative is to use a pair of infrared beams, usually fired horizontally. Infrared technology has the benefit of being less sensitive to snow, rain or heavy footsteps, but is vulnerable to high concentrations of airborne particulate, such as dust.

- Location technology. Described in section 3.4.1, automatic vehicle location can also be used in conjunction with treadles or infrared beams to determine the vehicle's location at the time boardings and alightings occur.

- Data management. It is necessary to transfer the data from the vehicle to other systems for processing and analysis. Options for this transfer include using the existing AVL system (if there is sufficient communications capacity), using removable storage media such as floppy disks or tapes, attaching a cable to a storage box and downloading to a laptop, or downloading over a dedicated radio frequency.

Maintenance needs will depend upon the counting method. Treadle mats will need to be replaced on a regular basis, depending upon wear. Infrared beams may need occasional calibration, but should otherwise need little maintenance. The operations and maintenance needs of the location technology were addressed in section 3.4.1. It is assumed that the AVL system will have communication capacity sufficient to be able to transmit passenger count data as well, so there would be no additional operations and maintenance requirements.

### *3.4.4 Smart Card System*

Smart cards could be issued to transit patrons and tourists for common fare medium and reward. Much like a credit card system, smart cards consist of cards carried by travelers and readers located on transit vehicles, at entrance gates to major tourist attractions, and at local stores. Unlike credit cards, smart cards allow transactions and other data to be electronically stored on the card. By observing where and how they are used, smart cards can be used to assist transportation officials in predicting transportation needs and identifying commonly used routes. Smart cards can also act as a congestion management tool by providing incentives, such as merchant discounts for using transit rather than personal vehicles.

There are two types of smart cards, both of which embed a microchip in a credit card. A contact smart card may be swiped like a credit card. A contactless smart card may be waved in close proximity to a reader such that it does not require contact with the reader. Because of the potential to increase processing speed, contactless cards are increasingly being used in transit applications. The operations and maintenance needs associated with the smart cards themselves are essentially non-existent. Smart card readers have proven to be durable and reliable in high-usage applications such as urban transit systems, and will require little maintenance.

### *3.4.5 On-Board Transit Safety Systems*

There are many advanced technology applications that may help to enhance the physical security of transit passengers.

- Surveillance cameras. Cameras may be installed on-board vehicles to provide additional surveillance. Images can be stored locally for downloading at a later time,

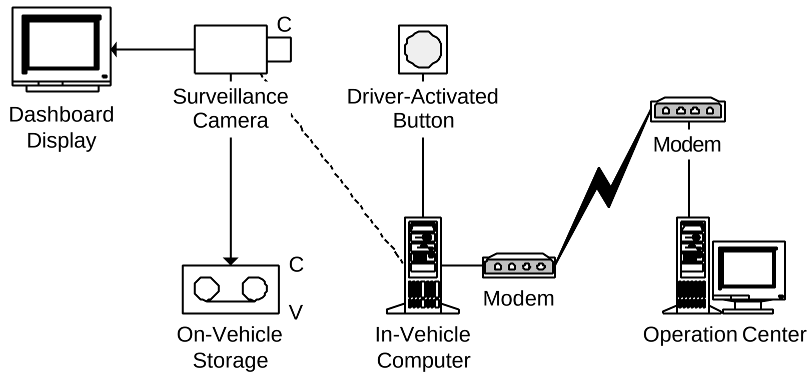


**Figure 3-30:** On-Board Transit Safety System.

or – if adequate bandwidth is available – can be transmitted at regular intervals to a dispatch center on a real-time basis. The components of an in-vehicle system are shown in Figure 3-30. The camera's images will be continually recorded onto an in-vehicle unit. There is the option of having a driver-activated system so that, when trouble occurs, images may be sent to the operation center.

- Passenger assistance buttons. When these buttons are depressed, the driver is notified through a silent dashboard indication. The driver then may use a monitor showing the surveillance camera image to determine what is happening and if any actions should be taken.

- Silent alarm. Related to the previous system is where a driver-activated alarm can silently trigger communications with the operation center to identify a crime is occurring. In combination with AVL, this can help to reduce response time and decrease the risk of serious physical injury.

In general, maintenance needs for these systems are fairly minimal because they are generally shielded from environmental exposure. Communication needs will depend upon whether the operating agency wishes to have images transmitted from vehicles to the center. If this is not deemed necessary, it should be possible to rely on the AVL communication system to support these transit surveillance functions as well. The various alarm buttons should be tested fairly frequently to ensure that they will work adequately when needed.

Transit safety systems may be installed at transit stops as well, especially areas where there are significant volumes of passenger traffic. If installed at a public area, more frequent maintenance would be recommended to ensure that any vandalism activity does not harm camera operations.

### *3.4.6 Traffic Signal Priority for Transit*

Similar to emergency vehicle signal preemption described in section 3.2.1, preferential signal treatment can be provided for transit vehicles. This can help to minimize delays at signalized intersections for transit vehicles by extending the green time long enough to permit the vehicle to pass through the intersection. This would have the advantage of reducing transit time, as well as improving the reliability of travel time estimates.

This system is physically identical to emergency vehicle traffic signal preemption system depicted in Figure 3-16. The only functional difference is in the programming at the controller. Operations and maintenance needs should therefore be exactly the same.

### *3.4.7 Automatic Vehicle Identification*

Automatic vehicle identification (AVI) differs from automatic vehicle location in that it is a localized system based on communication with a vehicle and a specific roadside fixed point. The traffic signal priority for transit system, as described last section, is similar in concept to AVI, although an AVI system would also permit unique identification of individual vehicles. AVI would allow subscribers to electronically bypass tourist attraction gates without stopping to pay fees. AVI could also be used to electronically debit accounts for paid parking areas.

Subscribers would be given small transponders to place in their windshield that will be read by an antenna at the automated gate. Users could pay for the service through a one-time, annual payment or on a per-use basis. In addition to transit vehicles, this system could be used by tourist attraction employees and concessionaires that use these gates daily, improving the throughput of entry gates and enhancing subscriber convenience. Eventually, the system could be expanded to other user groups such as annual pass holders of the destination attraction. By removing these vehicles from the queue, time savings will not only be realized by the AVI users but by other travelers passing through a gate.

The technology is similar to that described for AVL, and is shown in Figure 3-31. An in-vehicle unit transmits a signal to a reader at the entrance gate. Once a signal is received, the AVI reader accesses a central database to confirm that the vehicle may pass through and debit the vehicle's account if necessary. Once this is done, a green light indication is shown to the vehicle, signaling that it is acceptable to pass through the gate. An automatic gate may be added to reduce the probability of non-payment. If the vehicle account is invalid, a red light will be displayed and the driver will be instructed to speak to the attendant. For facilities with multiple entrances, it

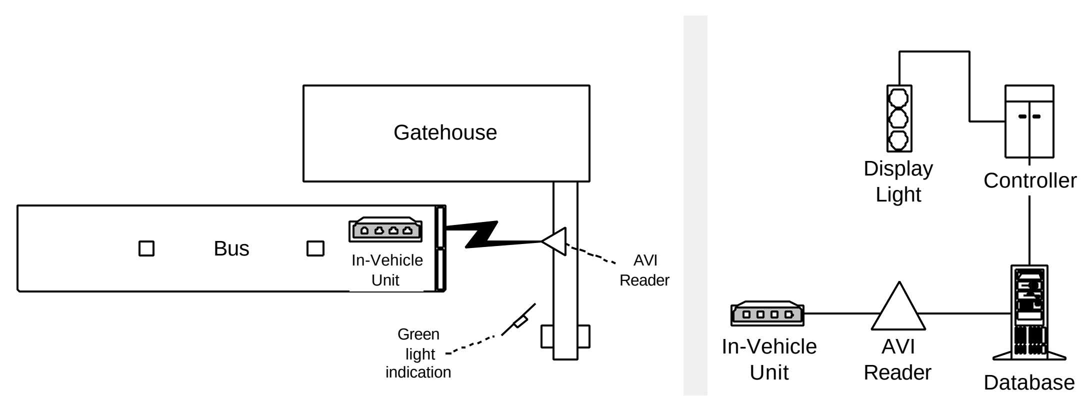


**Figure 3-31:** Automatic Vehicle Identification.

may be necessary to centralize AVI information on a common database for access at all entry points, especially if users are billed for the amount of time spent in a facility.

The technology for the AVI reader and in-vehicle units needs requires negligible ongoing maintenance.

### *3.4.8 Transit Traveler Information*

The use of AVL equipment can enhance transit information to travelers both on and off transit vehicles. For travelers on vehicles, AVL can be mixed with voice annunciation to provide announcements of upcoming stops. Once these systems are installed, operations and maintenance needs are negligible.

Another way to provide traveler information is to give transit riders waiting for the next bus to come to a particular stop. Bus stops may be equipped with electronic signage to indicate when the next vehicle is scheduled to arrive, based on real-time information. As shown in Figure 3-32, the data needs for this signage may be as minimal as a route number (for stops servicing multiple routes) and an estimated wait time in minutes. By minimizing the amount of data displayed, more different communications media may be applicable. Maintenance would consist primarily of ensuring that numbers on the sign remain legible, and that the sign's electronics are intact.

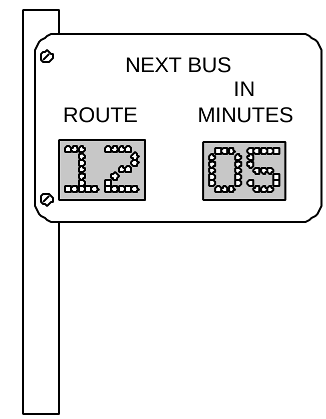


**Figure 3-32:** Transit Traveler Information at Bus Stop.

Transit information might also be disseminated on a pre-trip basis over media such as the Internet or television. This would require a software interface between the AVL system and the appropriate media so that information is translated properly from one system to another.

### *3.4.9 Parking Management and Information System*

Parking management systems are used to monitor the availability of parking use in near real-time, and inform and direct motorists to available parking through the use of variable message signs, highway advisory radio, phone service or the Internet. Figure 3-33 shows how such a system may be set up. Loop detectors set up at access points to parking facilities are connected to a central controller or computer. When the computer detects that the parking lot may be full, it sends a message to the parking server. The server, in term, would disseminate that information to motorists, such as through a variable message sign as shown.

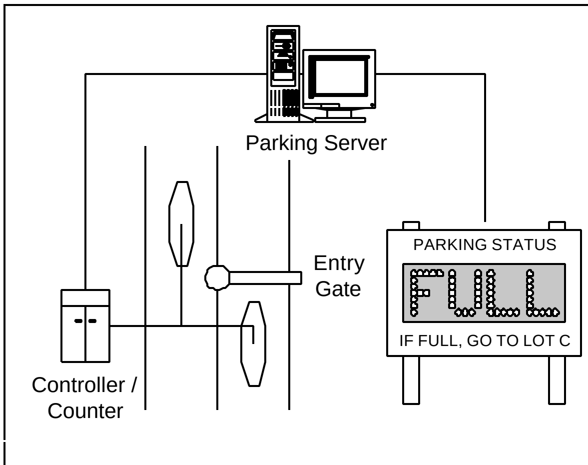


**Figure 3-33:** Parking Management and Information System.

Operation of this system requires that

parking access can be channelized to a fixed number of points, with fewer points being better from cost and management perspectives. Reliable real-time communications between satellite lots and the parking server would be necessary to ensure that accurate data is presented to motorists. Power will need to be provided to each parking lot as well. Maintenance needs will focus on the detectors to ensure that they are counting vehicles at an acceptable tolerance level. Additional maintenance will be necessary for whatever information dissemination method (e.g. variable message signs) is used.

### *3.4.10 Dynamic Ridesharing/Paratransit Service*

Dynamic ridesharing is a dial-in service that matches drivers and riders making the same trips on a real-time basis. The system is designed for jitney (non-fixed route) services. It will help reduce person-trips through enabling effective carpooling, and will increase mobility options for the mobility impaired. In areas where there are a greater number of transit-dependent residents, this service will provide the means to improve the efficiency of transit services and promote carpooling.

Figure 3-34 shows how this system would function. The system consists primarily of a dedicated server with a centralized database for storing information on potential riders and potential ride offers. When a trip request is received, the database is searched in order to identify whether there are any available rides with the same approximate time and destination as the request. Information on potential matches, including name and contact information, is provided to the requestor, who is then responsible for making the ridesharing arrangement.

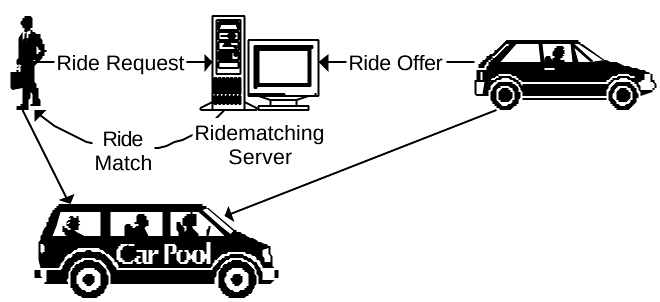


**Figure 3-34:** Dynamic Ridesharing System.

Because demand and supply of rides can change substantially over time, the most critical maintenance aspect of this system is regular, systematic purging of old records from the database. The server running the database would need to be regularly re-booted as well, to promote system stability.

### *3.4.11 Recreational Vehicle Park & Ride Lots with Surveillance*

Park and ride facilities for recreational vehicles will be located outside high visitation tourist destinations and/or National Parks and provide shuttle services to the special events or other major attractions within the study area. A sample architecture of this system is shown in Figure 3-35. The park and ride lots would have closed circuit television (CCTV) surveillance for security and to ensure patron satisfaction. CCTV images would be transmitted to the local enforcement agency, where images may also be stored for later viewing. This technology would involve merely the installation of CCTV and not the cost of providing shuttle service. Accessible existing parking lots (shopping plazas, etc.) facilities would be used where security can be provided.

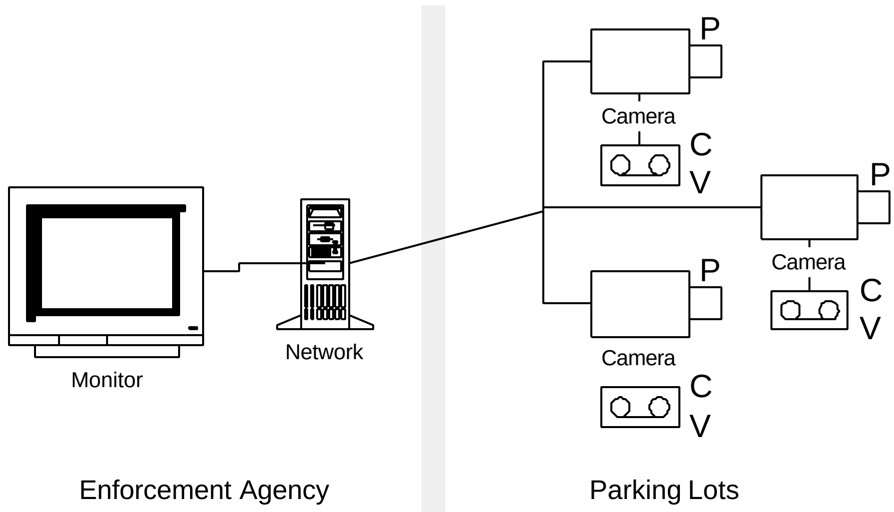


**Figure 3-35:** Recreational Vehicle Park & Ride Lots with Surveillance.

Maintenance of the cameras themselves is discussed in section 3.5.3. Attention would need to be paid to the computer hardware located in the field to ensure that its images are transferred properly, with date and time stamps being accurately denoted. At the enforcement agency, care would need to be taken to ensure that all camera images may be viewed acceptably. A video switch may be used to reduce the number of video monitors required.

## 3.5 Infrastructure Operations and Maintenance

Several technologies can assist in collecting, compiling and coordinating information about road and weather conditions. This section describes some of these technologies which may have applicability in the COATS project corridor.

### *3.5.1 Automatic Traffic Recorders/Traffic Monitoring Station*

Automatic traffic recorders or traffic monitoring stations are used to record traffic data, principally volume, at fixed locations. They may be used to help analyze seasonal and daily traffic volume trends at strategic sites on the highway network. They consist of a vehicle detector (usually an inductive loop), a controller that records detector actuations, and a controller cabinet, as shown in Figure 3-36. They are often capable of communicating via modem, so that their operation can be verified and evaluated remotely.

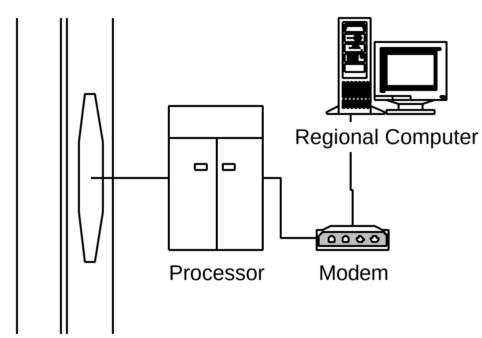


**Figure 3-36:** Automatic Traffic Recorder/Traffic Monitoring Station.

Maintenance of these systems is similar to that which would be performed for traffic signals. For example, detector equipment needs to be inspected periodically, especially for intrusive detection technology such as loops, to ensure that it is functioning properly. These systems require a reliable power supply, but beyond that do not require continual monitoring. Another key maintenance activity is calibration, which should be done regularly to ensure that the detection equipment is appropriately sensitive so that volumes are accurately measured.

### *3.5.2 Video Detectors*

An alternative to using loop detectors for measuring traffic flow is to use video detection equipment. A video detector costs more initially than a loop detector to install; however, because it is a non-intrusive technology, it does not require re-installation every time a roadway is resurfaced. A video detector consists of a camera with firmware that is able to count and track vehicle movements within its field of view. It interfaces with signal controllers in the same manner as inductive loops.

Video detection may be used in isolation to record traffic volumes and speeds for planning purposes, as shown in Figure 3-36. It may also be used in an intersection-based application to identify the presence of vehicles as a substitute for inductive loops or other detection technologies, as shown in Figure 3-37. In both cases, algorithms may be applied to detector data to identify when an incident is likely to have occurred, based on sudden changes in traffic volume or speed patterns.

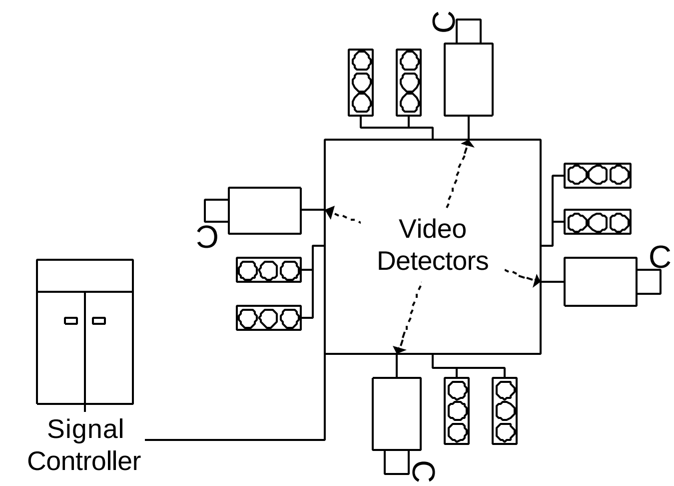


**Figure 3-37:** Video Detection at Signalized Intersections.

Maintenance needs for video detection systems have proven very minimal. The customer may perform annual lens cleanings, but it is recommended that the vendor perform most repair maintenance because of the specialized nature of the technology. Repair maintenance should rarely be necessary, such as in cases of lightning or knockdowns.

### *3.5.3 Closed-Circuit Television (CCTV) Surveillance*

Another tool to assist infrastructure management is the use of closed-circuit television (CCTV) cameras for remote surveillance. These would assist in remote verification of road and weather conditions, traffic conditions and incidents, and might also assist emergency personnel management in responding to incidents appropriately.

CCTV cameras differ from video detectors in two primary ways. First, through their pan-tilt-zoom capabilities, CCTV can view a wider area without needing re-calibration. Second, the cameras are built specifically to allow for viewing of images at remote locations on a real-time basis. The ability to view images real-time is dependent on the quality of communications links between the camera and the TMC. For real-time full-motion video images to be viewed remotely, fiber optics cable would likely be necessary. Since this is unlikely to be widely available in rural areas, images will be able to be transmitted only at intermittent intervals (perhaps every few minutes). One method of doing this is shown in Figure 3-38. The camera sends images to a character generator, which puts a date stamp on the image. The merged image is converted to a format for display on the Internet, and then is sent via modem to the network. From the network, the TMC operator can view the image.

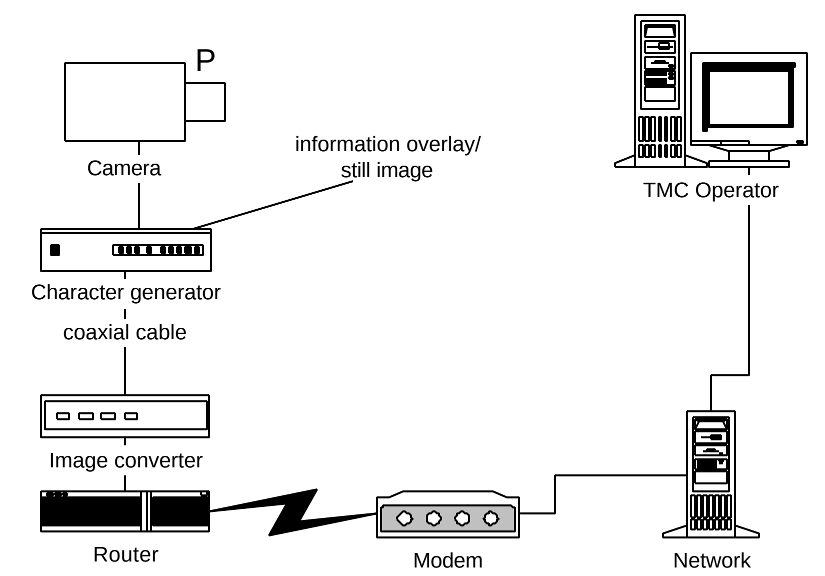


**Figure 3-38:** Closed-Circuit Television Camera.

Improvements in manufacturing have reduced considerably the need for repair maintenance of field cameras themselves. The most common maintenance need is preventative maintenance to clean the camera lens and inspect the cabling and cabinetry for corrosion. Problems may occur with communication between the camera and the operations center, depending upon the quality of power supply and environmental effects. Many solid-state devices, such as modems and routers, may be used in the image transmission process; these should need little maintenance. Real-time communications would likely require significant communications infrastructure, video switching equipment and a bank of video monitors, which tend to need infrequent but highly specialized maintenance.

### *3.5.4 Road and Weather Information Systems*

Road and weather information systems (RWIS) are used to gather key meteorological data near major roadways. Data collected by RWIS may have several applications, including expediting decisions on weather-induced closures or detours, providing pertinent traveler information, and assisting in deployment of roadway maintenance vehicles.

As shown in Figure 3-39, RWIS stations consist of tower-mounted and pavement-based sensors connected to a remote processing unit, which transmits weather information to a regional server database and/or the operations center.

Maintenance experience with RWIS stations shows that the sensors themselves are normally durable components. Annual preventative maintenance such as cleaning and calibration of sensors is normally adequate. Lightning strikes may affect individual sensors or the entire tower system, necessitating full equipment replacement. As was true for the CCTV system, the communication element between the field units and the operation center or remote database may be a problem, depending upon the quality of the power to the remote processing unit, as well as any solid-state devices that are used in the transmission process. Regional servers will need regular maintenance to clean the database, although this is not a very time-consuming activity.

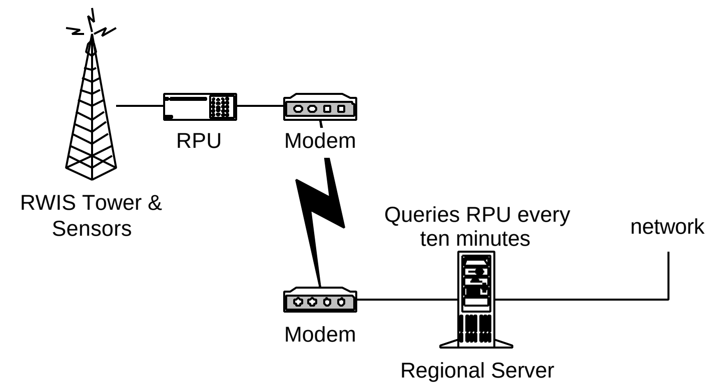


**Figure 3-39:** Road and Weather Information System.

### *3.5.5 Travel Time Estimation*

Obtaining real-time estimates of travel time through a corridor would allow for the notification of emergency response crews in the event of non-recurring congestion as caused by a roadway incident and the dissemination of real-time travel information to assist in en-route route choice. One common method for estimating travel times in a corridor is to determine the time elapsed between when the same vehicle (as identified by license plate number) passes two consecutive video checkpoints. The basic components of a travel-time estimation system using automated license plate readers, shown in Figure 3-40, are as follows.

- Camera. The camera captures the image of the vehicle's license plate. A digital color camera is recommended because of the increased speed of data transfer and assistance

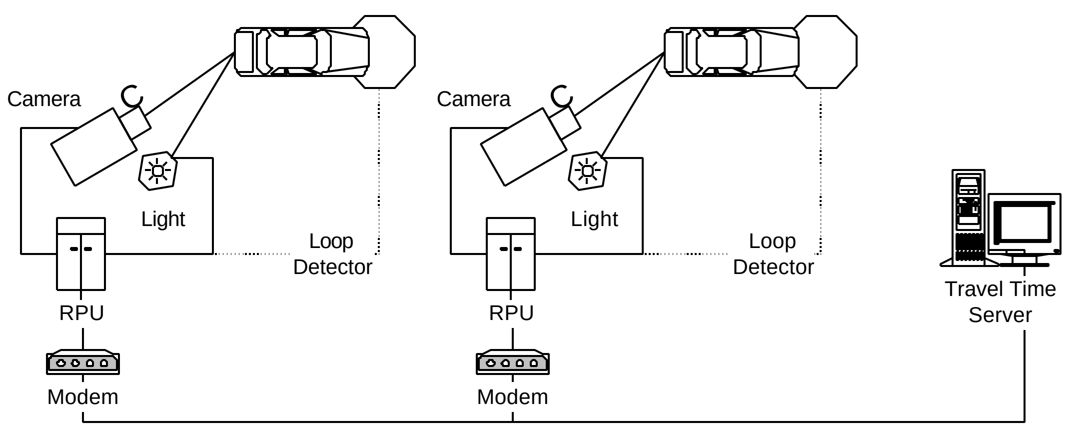


**Figure 3-40:** Travel Time Estimation.

in plate identification.

- Light source. A light source allows for operation at night and in poor visibility conditions. The light turns on at the same time as the camera to save energy and avoid too much motorist distraction. Infrared lighting is the most common light source used, because it is undetectable to the human eye and yet most cameras will pick it up.

- Triggering mechanism. The triggering mechanism is intended to fire the image-capturing components (i.e., the camera and light source) of the license plate reader when a plate is within the camera's field of view.

- Image processing algorithm. The image processing algorithm is used to identify the plate within the captured image, identify its state of origin and read its alpha-numeric code.

- Remote processing unit. An environmentally hardened microcomputer would be used to control the triggering mechanism, run the image processing algorithm and transmit the plate identification to the travel time server.

To measure travel times will require real-time communication from each of the checkpoints to a central server. The server matches observations collected at different checkpoints to identify vehicles that have passed between two or more checkpoints. After the server calculates average travel times, this information could be transmitted to the public through a variety of means, including the Internet, commercial radio, or other en-route traveler information systems.

Successful operation of this system requires continuous power supply to each field location, as well as real-time communications capability, ideally through dedicated landline connections. The primary maintenance need of the travel time estimation system is the proper upkeep of the remote processing units at each checkpoint. In addition to the preventative maintenance needs typical for a field computer, there is the possibility of cabinet knockdown due to the proximity of the cameras to the roadway. According to one vendor of such systems, maintenance needs of the field units have proven to be very minimal (23). The travel time server is also expected to need regular re-booting and database pruning, in order to ensure the system operates efficiently and effectively during times of peak traffic activity.

### *3.5.6 Highway Travel Conditions Reporting System*

The Highway Travel Conditions Reporting System (HTCRS) is a database application that allows operators to manually provide information about road conditions and incidents (24). The relation of the HTCRS to other traveler information systems is shown in Figure 3-41. It is intended to be a secondary information source beyond information collected from cameras, RWIS and other field devices. The HTCRS database will be structured such that information from this database may be accessed by and disseminated to other information systems, such as kiosks or the Internet, to allow users to find detailed traveler information for specific areas or highways.

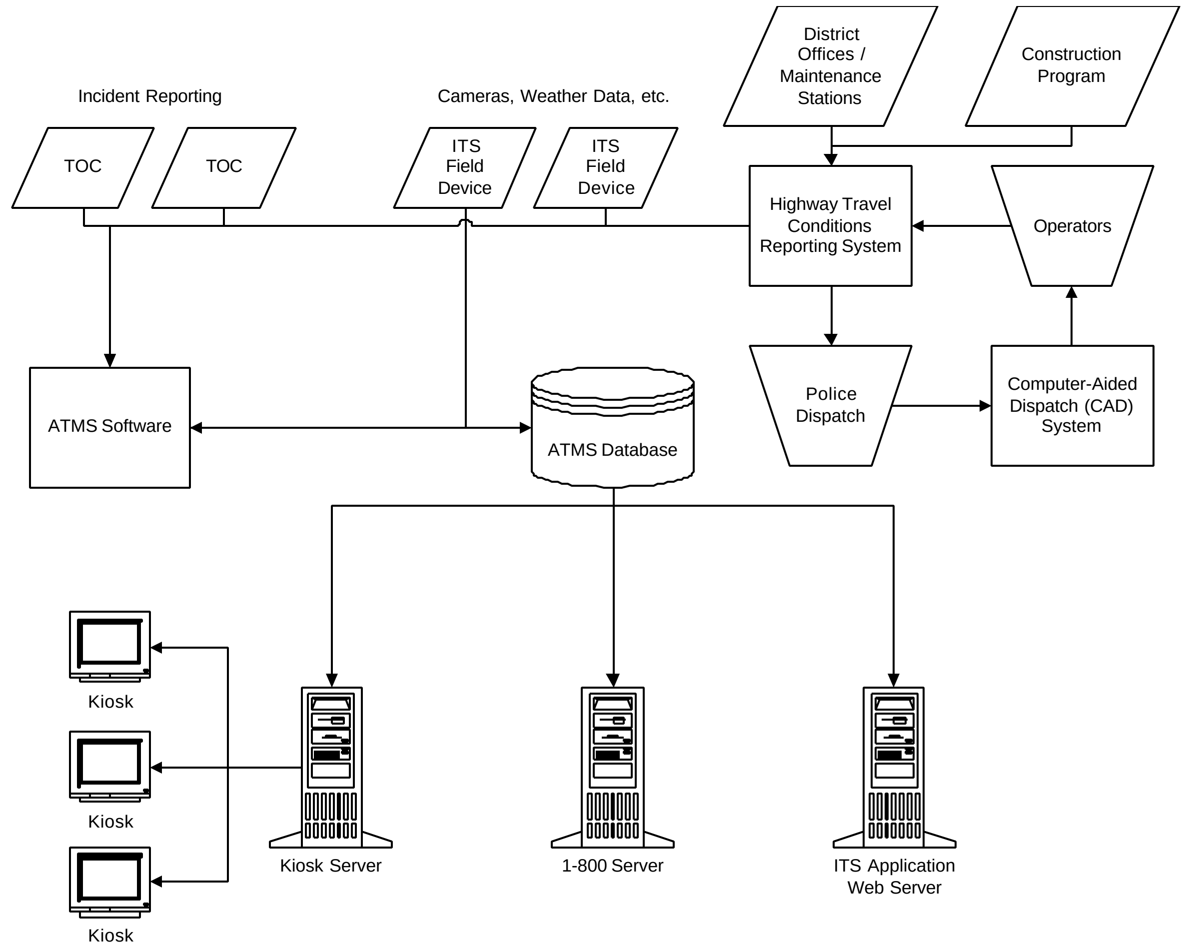


**Figure 3-41:** Pre-Trip Traveler Information.

Related to the HTCRS will be an application that will interface with the state police's CAD system. The application will, through both manual and automatic selection, identify recent entries in the CAD database which require some type of intervention with respect to travel conditions. The interface will preserve some of the data fields created by the CAD system, such as time and location of the report, and will allow for additional fields of data to be created, such as number of lanes blocked (25). This works toward the long-term goal of having a single entry input system.

This system is primarily a software overlay developed by ODOT, which may be adopted by the California Department of Transportation (Caltrans) depending upon compatibility with other systems. Maintenance needs will focus primarily on database purging and routine server maintenance activities.

### *3.5.7 Regional Server/Coordination Software*

This system could build upon existing hardware, connections and software to develop an integrated method for sharing information and management responsibilities for incidents among the various agencies and departments involved. This is shown in Figure 3-41 as ATMS, which stands for advanced traffic management system.

The most significant complication with this system is initial set-up. Because of potential differences in networks and data conventions between California and Oregon, significant effort will need to be spent on ensuring seamless integration of information between states. This would allow travelers to find pre-trip travel information across state lines in one stop. Once the system is installed, the maintenance needs for this system will consist primarily of database purging and regular re-booting.

### *3.5.8 Satellite Traffic Operations Center*

The Satellite Traffic Operations Center (SOC) serves as a centralized control center to effectively monitor and manage traffic, analyze data from multiple sources, and operate other systems. The SOC will also assist with traffic and incident management coordination. The center will consist one or more operators who have the responsibility of observing current traffic and weather conditions (through a variety of means) and making appropriate decisions based on that information. Decisions could range from how to disseminate information about a road closure to coordinating emergency response to an incident. As defined here, the center also includes the "brick and mortar" costs of infrastructure management, including:

- telecommunications support for operators and computer networks,
- power to building and central servers,
- building costs such as heating and maintenance, and
- vehicles to access and service field devices.

The operations and maintenance needs of these centers depend substantially on working relationships that may be establish between the transportation centers and other institutions, such as the state police. In Oregon, for example, state police dispatch is collocated with transportation operations center (TOC) functions in several rural locations, which reduces costs to the Oregon Department of Transportation.

## 3.6 Fleet Operations and Maintenance

This section will review two advanced technologies that may have particular application to fleet operation and maintenance activities.

### *3.6.1 Fleet Monitoring*

AVL was discussed in section 3.4.1 in connection with transit vehicles. It has similar potential for fleet operations. AVL can help fleet managers to more efficiently monitor and route vehicles. In-vehicle sensors can be installed to communicate vehicle activity via the on-board modem. Potential activities that could be monitored include chemical dispersion and plow activity for maintenance vehicles.

Beyond the basic maintenance needs associated with AVL, the in-vehicle sensors will need some maintenance. One operator of a maintenance vehicle fleet has found that washing down sensors regularly is the only maintenance that is required (26).

### 3.6.2 Probe Vehicle Instrumentation

Another application of AVL that has application to fleets is the use of vehicles as probes. This is done by instrumenting vehicles with probes to detect pavement and weather conditions in areas where chronically bad weather conditions occur. Vehicles could transmit stored data periodically or save data and upload later. The operations and maintenance needs of this system would be similar to the fleet monitoring system described in section 3.6.1.

## 3.7 Commercial Vehicle Operations

While most of the advanced technologies discussed so far have applications to all types of highway vehicles, some applications have particular benefit to commercial vehicles. Commercial vehicle fleet managers may find some benefit in having AVL to improve fleet efficiency and responsiveness. There are roadside infrastructure enhancements which may also help to improve operations for commercial vehicles. Some of these enhancements are discussed in this section.

### 3.7.1 Electronic AVI Preclearance

To reduce congestion at roadside weigh stations, AVI may be used to clear motor carriers in advance of the weigh station. This helps to increase efficiency for the carriers and helps enforcement personnel to effectively focus enforcement and compliance efforts. To perform this pre-clearance, the following elements as shown in Figure 3-42 would be necessary. A motor carrier would gain approval for pre-clearance through the appropriate regulatory agency, such as the state department of transportation. Once pre-clearance has been granted, the carrier would obtain transponders for each vehicle. Each transponder would contain a unique identification number that would have information stored in a central database. A cluster of equipment is installed about a mile upstream of the conventional weigh station. The equipment includes inductive loops for determining vehicle speed, axle sensors to count vehicle axles, overheight detectors, AVI sensors to read transponders, and automatic vehicle classification (AVC) equipment. When a particular truck passes under the AVI reader, the unique identification number is read. This information is verified against the database to ensure that the carrier remains in appropriate compliance. If not, a red light will be shown to the vehicle a short distance downstream, to indicate that the vehicle should pull into the conventional weigh station.

Electronic AVI pre-clearance sites may also integrate weigh-in-motion technology to improve enforcement of weight restrictions. This technology is discussed in the following section.

Transponders require no maintenance, and can rely on battery power for many years of operation. For most of the other equipment, regular inspection maintenance activities are recommended.

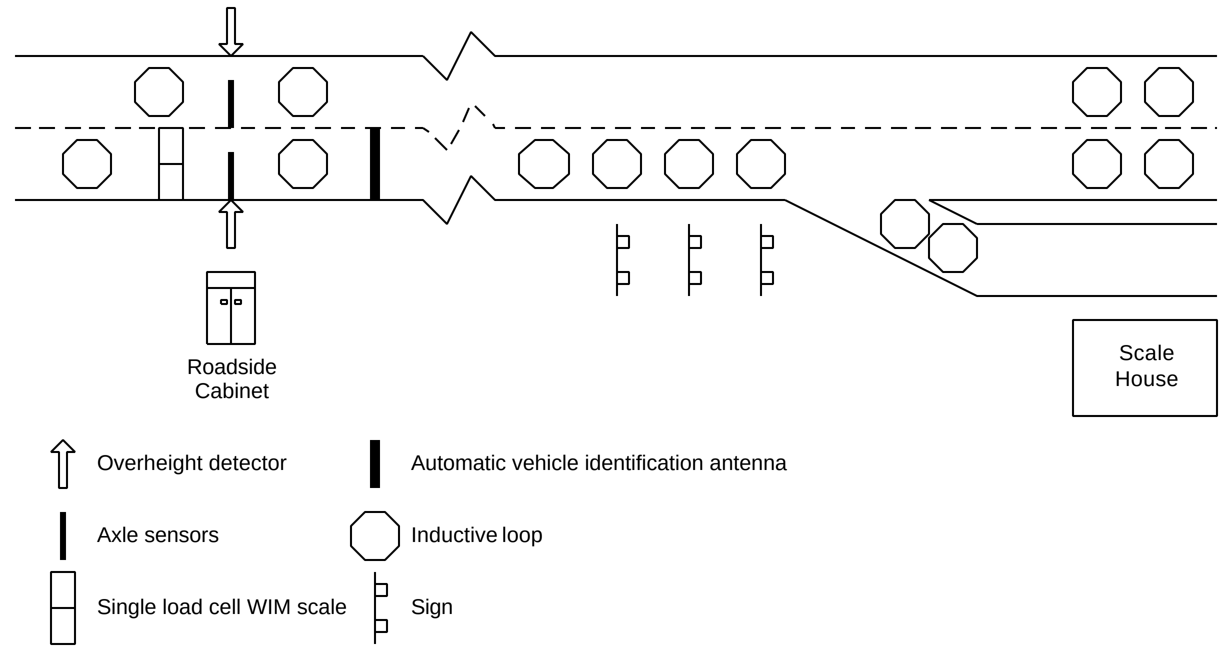


**Figure 3-42:** Electronic Pre-Clearance with Weigh-in-Motion.

### *3.7.2 Weigh-in-Motion*

The purpose of a weigh-in-motion (WIM) system is self-explanatory: it is designed to allow vehicles to be weighed while in motion. WIM systems in the United States are designed primarily to weigh commercial vehicles at freeway speeds for the purposes of enforcing weight limits on the highways. These systems generally serve to supplement or replace existing conventional weigh stations. In addition, this technology may be used for planning purposes without respect to enforcement activities.

Maintenance of WIM stations will focus primarily on re-calibration activities for the scales, which need to be performed every six months. Scales need to be replaced every few years as well, with the replacement cycle depending upon the particular scale technology that is being employed.

### *3.7.3 Downhill Speed Advisory System*

The purpose of the downhill speed advisory system (DSAS) is to provide commercial vehicles with roadside VMS to warn them of excessive traveling speeds, based on weather conditions and vehicle characteristics, including weight and dimensions. It is intended to complement runaway truck ramps and potentially reduce the number of times they would be needed (27).

A typical DSAS configuration is shown in Figure 3-43. The system includes WIM equipment that measures individual vehicle weights and dimensions. A field processor determines the maximum safe speed for each vehicle based on the operating characteristics of

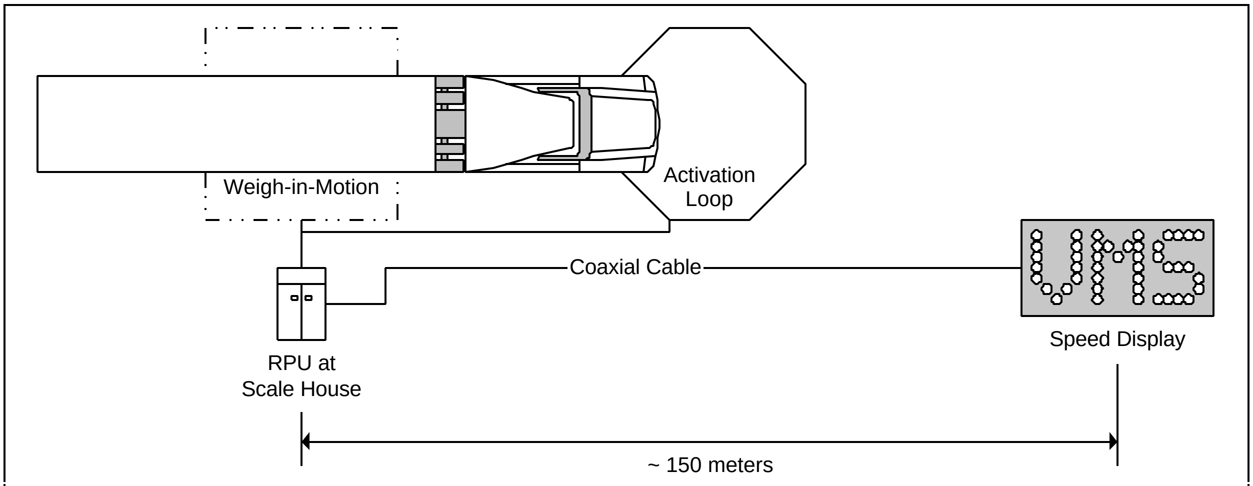


**Figure 3-43:** Downhill Speed Advisory System.

truck braking systems. When the truck passes over an activation loop, a downstream VMS is triggered to display the calculated safe speed (27). Since the WIM and VMS will likely be separated by a relatively short distance, communications between the WIM and VMS might be provided through coaxial cable.

In terms of maintenance needs, DSAS maintenance needs should reflect a combination of the maintenance needs of its WIM and VMS components. Regular calibration of the WIM scales and cleaning and testing of the VMS would be necessary.

### *3.7.4 Hazardous Materials Management*

A special type of incident response is necessary when hazardous materials (HazMat) are involved in order to properly address their consequences and cleanup. This type of incident response involves the electronic tagging of HazMat shipments on commercial vehicles, integrated with a database that would denote vehicle contents. This database would, in turn, be immediately available to emergency response personnel if necessary. This is shown in Figure 3-44.

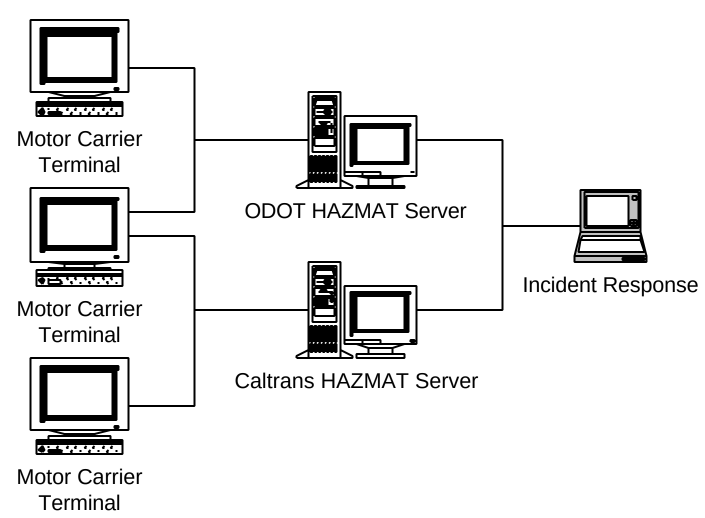


**Figure 3-44:** Hazardous Materials Management.

To maintain the integrity of a HazMat response system, it is recommended that a separate server manage the HazMat shipment database. Shippers would access this system fairly frequently in order to provide information on shipments currently en-route. Maintenance needs would therefore focus on preserving the integrity of the server and the database.

## 3.8 Infrastructure Support

In addition to the technologies reviewed under each of the seven critical program areas, there are systems that are necessary to supporting the field technologies to ensure effective and efficient operation. This section highlights some of the operations and maintenance needs associated with these systems.

### *3.8.1 Wireline Communications*

Wireline communications refers to a broad class of communications media, including coaxial, twisted-pair and fiber optic cable, in which signals are sent over a physical media from one point to another. These media differ in their cost and functionality, and are therefore not readily interchangeable. Maintenance needs of wireline communication systems are typically minimal. Only when cable is severed (such as through fallen telephone poles or digging into underground cable) is repair maintenance required. Reflectometer testing for fiber optic cable is also recommended on an infrequent basis (every two years) in order to test signal strength. Wireline communications are expensive initially. For this reason, one or two isolated ITS applications will not typically be able to justify the capital cost of laying cable.

Special training is typically necessary for maintenance of wireline communications systems, especially for fiber optics. This training is necessary to ensure that when repairs are made that the integrity of the communications network is not harmed.

### *3.8.2 Wireless Communications*

Where wireline communications are impractical, wireless communications – using the air as the communications media – may be applicable. Some of the more prominent choices for wireless communications include cellular telephone, cellular digital packet data, and radio. Wireless communications systems require a supporting infrastructure of towers to transmit and repeat signals. They may not transmit information effectively or consistently to isolated mountain valleys, which may pose problems in some rural applications.

Maintenance needs for wireless communications are focused on the towers and buildings. Regular maintenance is needed to ensure that frequency and power levels are appropriate.

### *3.8.3 Coordination Activities*

The final element in maintaining the ITS infrastructure is to examine the costs associated with coordination, tracking and logging of maintenance activities. Failure to consider who will coordinate maintenance activities would cause device operations to suffer. Effective coordination will require a centralized database to log and track maintenance activities, as well as a staff person in each region to whom maintenance coordination activities are delegated.

# 4 BUDGET

This chapter will summarize the operations and maintenance (O&M) costs for each device that may be included in the ITS infrastructure for the COATS study region. Developing these estimates requires many assumptions that will be detailed in the sections that immediately follow.

## 4.1 Operations Costs

Because of the ambiguity of many operational costs, attempts will be made to quantify only two of the costs discussed in Chapter 2: power and communications at field devices. Costs associated with the center will depend upon specific decisions to be made about the organization, structure, purpose and size of each center. Costs associated with the vehicles and communications between the center and field devices are also subject to decisions which are beyond the scope of this document.

### *4.1.1 Power*

The power consumption of individual ITS devices was estimated based on typical power consumption levels of each component (28-54). These power consumption levels reflected that some components would not be requiring power continuously, but only when certain conditions are present, such as a flashing beacon indicating that water is on the roadway.

This power level was applied to rate structures obtained from several utility companies, which are shown in Table 4-1, in order to obtain a range of monthly power costs. These costs were then averaged to produce device-level estimates. A range of costs was generated for each device in order to reflect the variability that may exist in utility costs between regions.

### *4.1.2 Communications*

The cost of communications support at the field device level will depend upon the amount of data that needs to be transmitted. For the sake of simplicity, communications needs for each device were classified into one of four categories:

| Utility Company | Geographic Area | Power Usage (per month) | Base Charge (per month) | Energy Charge (per kWh) |
|---|---|---|---|---|
| Pacific Power & Light | Oregon | Up to 100 kW | $10.15 | $0.0632 |
| | California | Less than 20 kW | $10.00 | $0.0927 |
| | | 20 kW and over | $10.00 | $0.0730 |
| Pacific Gas & Electric | California | Less than 500 kW | $8.10 | $0.1253 |
| Columbia River PUD | Oregon | Less than 30 kW | $8.00 | $0.0552 |
| Midstate Electric Cooperative | Central Oregon | Up to 10,000 kW | $14.00 | $0.0510 |

**Table 4-1:** Power Cost Structures for Various Utility Companies.
(Sources: 55-60)

- no communications needed at the device level,
- dial-up connection,
- frame-relay connection, or
- T-1 connection.

Costs for each service were estimated from agency experience as well as a review of some telecommunications companies' rate policies (61-65).

#### 4.1.3 Summary of Operations Costs

Table 4-2 summarizes the estimated power and telecommunications costs by device. It is important to note that these are not fully comprehensive operations costs, as additional time may be required for staff monitoring, vehicle usage, and other costs which were mentioned in Chapter 2.

### 4.2 Maintenance Activities

The predominant recurring cost for intelligent transportation systems applications is maintenance, including both preventative or scheduled maintenance tasks and repair or emergency maintenance tasks. This section will summarize the methodology used to estimate maintenance costs for the ITS infrastructure[8].

#### 4.2.1 Staffing

Developing estimates of staffing cost associated with maintenance involved examining a series of steps.

- Repair time. Maintenance technicians will be dispatched for both preventative and repair maintenance activities. For each type of activity, estimates of typical annual requirements were developed in terms of number of visits per year, number of hours per visit, and type of skill set required. Moreover, in order to fully describe the appropriate skill set required for each device, it was important to look at each device in terms of components, such as sensors, communications, field processor/controller, software, center sub-systems and information delivery. These requirements further reflected that there may be hand-offs because the person dispatched initially to make a repair may not be able to diagnose the problem, so another technician needs to be sent.

- Travel time. Travel time was factored in for each repair visit, because it can represent a significant time cost in rural deployments. Travel times were estimated within each of the regions included in the COATS project corridor. It was assumed that when higher-level technicians needed to be summoned that they would come from each DOT's headquarters office.

[8] The methodology used in this section is identical to that employed in a maintenance plan developed by the Western Transportation Institute at Montana State University-Bozeman (WTI) for ODOT (1)

| | | Power | | | Total | | |
|---|---|---|---|---|---|---|---|
| **Device** | **Tel.** | **Low** | **Avg.** | **High** | **Low** | **Avg.** | **High** |
| **Traveler Safety and Security** | | | | | | | |
| Motorist-Aid Call Boxes | $ 40 | $ 120 | $ 140 | $ 170 | $ 160 | $ 180 | $ 210 |
| Cellular Call-In | - | - | - | - | - | - | - |
| Computer-Aided Dispatch | - | - | - | - | - | - | - |
| Queue Detection System | - | 140 | 160 | 180 | 140 | 160 | 180 |
| Intersection Advance Warning Signing | - | 140 | 160 | 190 | 140 | 160 | 190 |
| Intersection-Based Incident Detection System | 40 | 140 | 160 | 180 | 180 | 200 | 220 |
| Advanced Bicycle/Pedestrian Warning | - | 140 | 160 | 180 | 140 | 160 | 180 |
| Dynamic Warning Variable Message Signing | - | 120 | 160 | 190 | 120 | 160 | 190 |
| Variable Speed Limit Systems | 40 | 180 | 200 | 220 | 220 | 240 | 260 |
| Anti-Icing System for Roads and Bridges | 40 | 120 | 150 | 180 | 160 | 190 | 220 |
| Narrow Lane Width Advance Warning System | - | 140 | 160 | 190 | 140 | 160 | 190 |
| Automated Flood Warning | 40 | 120 | 150 | 180 | 160 | 190 | 220 |
| Automated Gate Closure System | 40 | 140 | 160 | 190 | 180 | 200 | 230 |
| Mayday Systems | - | - | - | - | - | - | - |
| **Emergency Services** | | | | | | | |
| Signal Preemption for Emergency Vehicles | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| Incident Response Vehicles | 40 | - | - | - | 40 | 40 | 40 |
| Pre-planned Detour Routes | - | - | - | - | - | - | - |
| **Tourism and Traveler Information Services** | | | | | | | |
| Alphanumeric Paging | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| (1) 1-800 Number | - | - | - | - | - | - | - |
| Television | - | - | - | - | - | - | - |
| (1) Internet | 540 | - | - | - | 540 | 540 | 540 |
| Kiosks | 110 | 170 | 190 | 210 | 280 | 300 | 320 |
| Changeable Message Signs | - | 120 | 150 | 180 | 120 | 150 | 180 |
| Variable Message Signs | 40 | 120 | 170 | 200 | 160 | 210 | 240 |
| Work Zone Delay Advisory System | - | 110 | 160 | 190 | 110 | 160 | 190 |
| Highway Advisory Radio | 40 | 110 | 140 | 170 | 150 | 180 | 210 |
| **Public Traveler/Mobility Services** | | | | | | | |
| Automatic Vehicle Location | $ 40 | $ - | $ - | $ - | $ 40 | $ 40 | $ 40 |
| Transit Vehicle Routing/Scheduling Software | - | - | - | - | - | - | - |
| Automated Passenger Counting System | - | - | - | - | - | - | - |
| Smart Card System | - | 100 | 140 | 170 | 100 | 140 | 170 |
| On-Board Transit Safety Systems | - | - | - | - | - | - | - |
| Traffic Signal Priority for Transit | - | - | - | - | - | - | - |
| Automatic Vehicle Identification | - | 190 | 210 | 230 | 190 | 210 | 230 |
| Transit Traveler Information | 40 | 130 | 160 | 180 | 170 | 200 | 220 |
| Parking Management and Information System | 40 | 190 | 200 | 220 | 230 | 240 | 260 |
| Dynamic Ridesharing/Paratransit Service | - | - | - | - | - | - | - |
| RV Park & Ride Lot w/ Surveillance | | 130 | 160 | 180 | 130 | 160 | 180 |

**Table 4-2:** Estimated Telephone and Power Costs.

| | | Power | | | Total | | |
|---|---|---|---|---|---|---|---|
| **Device** | **Tel.** | **Low** | **Avg.** | **High** | **Low** | **Avg.** | **High** |
| **Infrastructure Operations and Maintenance** | | | | | | | |
| Auto. Traffic Recs./Traffic Monitoring Station | $ 40 | $ 140 | $ 160 | $ 180 | $ 180 | $ 200 | $ 220 |
| Video Detectors | - | 150 | 170 | 190 | 150 | 170 | 190 |
| Closed-Circuit Television (CCTV) Surveillance | 110 | 120 | 150 | 170 | 230 | 260 | 280 |
| Road and Weather Information Systems | 40 | 170 | 190 | 210 | 210 | 230 | 250 |
| Travel Time Estimation | 40 | 130 | 160 | 180 | 170 | 200 | 220 |
| Highway Travel Conditions Reporting System | - | - | - | - | - | - | - |
| Regional Server/Coordination Software | - | - | - | - | - | - | - |
| Satellite Traffic Operations Center | - | - | - | - | - | - | - |
| **Fleet Operations and Maintenance** | | | | | | | |
| Fleet Monitoring | $ 40 | $ - | $ - | $ - | $ 40 | $ 40 | $ 40 |
| Probe Vehicle Instrumentation | 40 | - | - | - | 40 | 40 | 40 |
| **Commercial Vehicle Operations** | | | | | | | |
| Electronic AVI Preclearance | $ 40 | $ 180 | $ 200 | $ 210 | $ 220 | $ 240 | $ 250 |
| Weigh-in-Motion | 40 | 180 | 200 | 210 | 220 | 240 | 250 |
| Downhill Speed Advisory System | 40 | 190 | 210 | 230 | 230 | 250 | 270 |
| Hazardous Materials Management | - | - | - | - | - | - | - |
| **Infrastructure Support** | | | | | | | |
| Wireline Communications | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| Wireless Communications | - | - | - | - | - | - | - |
| Coordination Activities | - | - | - | - | - | - | - |

(1) Communications cost will depend upon usage.

**Table 4-2:** Estimated Telephone and Power Costs.. (cont.)

- Inventory levels. Because future inventory levels for these technologies are uncertain, maintenance cost estimates were prepared on a per-device estimate. There are two disclaimers which are critical to observe. First, travel time on preventative maintenance activities will tend to decrease as deployment levels increase, because multiple devices may be serviced on the same trip.

  Second, some devices, such as RWIS, have an architecture where there can be an indeterminate number of field devices corresponding to a single center sub-system, such as a server. For each device, an estimate was made regarding the number of field devices which may be expected to be attached to a sub-system in a particular region. These estimates are shown in Table 4-3. As the number of field devices increase beyond these levels, average per-device maintenance costs could therefore be expected to decrease.

- Salary and overhead. In order to establish a consistent base, salary levels were obtained from the state of Oregon in order to estimate the typical staff costs for various skill levels. Overhead and fringe benefits were estimated to be 70 percent of staff salary levels. This overhead may be used to include operations costs, such as building and vehicle usage.

| Device | Number of Field Devices Per Server |
|---|---|
| Icy Bridge Detectors | 10 |
| Oversize Load Detectors | 10 |
| Visibility Detection Systems | 10 |
| Variable Speed Limit Systems | 10 |
| Automated Flood Warning | 10 |
| Automated Gate Closure System | 10 |
| Incident Response Vehicles | 10 |
| Kiosks | 10 |
| Variable Message Signs | 10 |
| Automatic Vehicle Location | 100 |
| On-Board Transit Safety Systems | 10 |
| Automatic Vehicle Identification | 5 |
| Transit Traveler Information | 100 |
| Parking Management and Information System | 10 |
| RV Park & Ride Lots with Surveillance | 10 |
| Closed-Circuit Television (CCTV) Cameras | 10 |
| Road and Weather Information System (1) | 10 |
| Travel Time Estimation | 10 |
| Satellite Traffic Operations Center (2) | 1 |
| Fleet Monitoring | 100 |
| Probe Vehicle Instrumentation | 100 |
| Electronic AVI Preclearance | 10 |
| Weigh-in-Motion | 10 |

(1) It is assumed that there will be one statewide server to correspond to each state's regional servers.
(2) Each TOC is assumed to have six computer workstations.

**Table 4-3:** Assumed Number of Field Devices Per Server.

### *4.2.2 Spare Parts and Emergency Device Replacement*

Another critical component of the maintenance budget is the cost associated with spare parts or emergency device replacement. Spare parts costs are associated with components that are expected to wear frequently and for which replacement rates can be estimated, such as light bulbs. Emergency device replacement is necessary to consider because events like lightning or seismic disturbances may render a device completely inoperative. Having funds set aside for emergency device replacement can make sure that a device can be replaced without having to wait for a new allocation in the short-range transportation improvement program.

### *4.2.3 Other Costs*

Several other costs could factor into maintenance, but are not considered in this document.

- Vendor Support. Some maintenance activities are so specialized that DOT staff could not perform them. The costs of this vendor support have not been considered, as this will depend upon the nature of procurement and vendor selection.

- Contracting. For budgeting purposes, it was assumed that no maintenance would be contracted. The cost of contracting for maintenance on any particular device could differ based on a number of factors, such as contract structure and terms and contractor proficiency.

- Test/Specialized Equipment. It may be necessary to acquire additional equipment to diagnose, test and repair ITS devices in a timely fashion. The necessity of acquiring such equipment will need to be evaluated on a regional level, based on existing needs and future deployment levels.

## 4.3 Total Operations and Maintenance Costs

Table 4-4 summarizes estimated costs of operations (power and telecommunications only) and maintenance for each of the ITS devices which may be included in the COATS project infrastructure.

| Device | Maintenance Skill Set: Electrical | Hardware | Software | Radio | Testing | Fiber Optics | Annual Costs: *Power & Telephone* Low | Average | High | *Spares & Replace-ments* | *Maintenance Sub-Total* Low | Average | High | *Total* Low | Average | High |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Traveler Safety and Security** | | | | | | | | | | | | | | | | |
| Motorist-Aid Call Boxes | | | | | X | | $ 160 | $ 180 | $ 210 | $ 680 | $ 50 | $ 50 | $ 60 | $ 890 | $ 910 | $ 950 |
| Cellular Call-In | | | | | | | - | - | - | - | - | - | - | - | - | - |
| Computer-Aided Dispatch | | X | X | | | | - | - | - | 50 | 1,380 | 1,530 | 1,680 | 1,430 | 1,580 | 1,730 |
| Queue Detection System | X | | | | | | 140 | 160 | 180 | 300 | 1,610 | 1,880 | 2,210 | 2,050 | 2,340 | 2,690 |
| Intersection Advance Warning Signing | X | | | | | | 140 | 160 | 190 | 480 | 2,510 | 2,910 | 3,400 | 3,130 | 3,550 | 4,070 |
| Intersection-Based Incident Detection System | X | X | X | | | | 180 | 200 | 220 | 420 | 4,210 | 5,080 | 6,150 | 4,810 | 5,700 | 6,790 |
| Advanced Bicycle/Pedestrian Warning | X | | | | | | 140 | 160 | 180 | 250 | 1,610 | 1,880 | 2,210 | 2,000 | 2,290 | 2,640 |
| Dynamic Warning Variable Message Signing | X | X | X | | | | 120 | 160 | 190 | 1,390 | 2,080 | 5,190 | 4,050 | 3,590 | 6,740 | 5,630 |
| Variable Speed Limit Systems | X | X | X | | | | 220 | 240 | 260 | 3,850 | 3,930 | 5,200 | 6,750 | 8,000 | 9,290 | 10,860 |
| Anti-Icing System for Roads and Bridges | X | X | X | | | | 160 | 190 | 220 | 3,080 | 2,260 | 4,640 | 3,330 | 5,500 | 7,910 | 6,630 |
| Narrow Lane Width Advance Warning System | X | | | | | | 140 | 160 | 190 | 500 | 2,580 | 2,980 | 3,460 | 3,220 | 3,640 | 4,150 |
| Automated Flood Warning | X | X | | | | | 160 | 190 | 220 | 280 | 1,730 | 2,080 | 2,480 | 2,170 | 2,550 | 2,980 |
| Automated Gate Closure System | X | X | X | | | | 180 | 200 | 230 | 280 | 3,210 | 3,860 | 4,660 | 3,670 | 4,340 | 5,170 |
| Mayday Systems | | X | X | | | | - | - | - | 80 | 3,380 | 3,750 | 4,130 | 3,460 | 3,830 | 4,210 |
| **Emergency Services** | | | | | | | | | | | | | | | | |
| Traffic Signal Preemption for Emergency Vehicles | X | | | | | | $ - | $ - | $ - | $ 110 | $ 210 | $ 260 | $ 320 | $ 320 | $ 370 | $ 430 |
| Incident Response Vehicles | X | X | X | | | | 40 | 40 | 40 | 2,980 | 1,400 | 1,560 | 1,720 | 4,420 | 4,580 | 4,740 |
| Pre-planned Detour Routes | | | X | | | | - | - | - | - | 20 | 20 | 20 | 20 | 20 | 20 |
| **Tourism and Traveler Information Services** | | | | | | | | | | | | | | | | |
| Alphanumeric Paging | | | X | | | | $ - | $ - | $ - | $ - | $ 100 | $ 110 | $ 120 | $ 100 | $ 110 | $ 120 |
| 1-800 Number (1) | X | X | X | | | | - | - | - | 80 | 16,780 | 18,640 | 20,500 | 16,860 | 18,720 | 20,580 |
| Television | | X | | | | | - | - | - | 80 | 6,090 | 6,770 | 7,450 | 6,170 | 6,850 | 7,530 |
| Internet (1) | | X | X | | | | 540 | 540 | 540 | 80 | 51,100 | 56,780 | 62,460 | 51,720 | 57,400 | 63,080 |
| Kiosks | | X | X | | | | 280 | 300 | 320 | 1,510 | 1,870 | 2,170 | 2,390 | 3,660 | 3,980 | 4,220 |
| Changeable Message Signs | X | | | X | | | 120 | 150 | 180 | 500 | 1,210 | 1,470 | 1,750 | 1,830 | 2,120 | 2,430 |
| Variable Message Signs | X | X | X | | X | | 160 | 210 | 240 | 7,370 | 2,130 | 5,380 | 4,540 | 9,660 | 12,960 | 12,150 |
| Work Zone Delay Advisory System | X | X | X | | | | 110 | 160 | 190 | 1,990 | 730 | 10,240 | 15,430 | 2,830 | 12,390 | 17,610 |
| Highway Advisory Radio | X | X | | X | | | 150 | 180 | 210 | 5,250 | 2,150 | 2,630 | 3,210 | 7,550 | 8,060 | 8,670 |
| **Public Traveler/Mobility Services** | | | | | | | | | | | | | | | | |
| Automatic Vehicle Location | | X | X | X | | | $ 40 | $ 40 | $ 40 | $ 130 | $ 80 | $ 90 | $ 100 | $ 250 | $ 260 | $ 270 |
| Transit Vehicle Routing/Scheduling Software | | | X | | | | - | - | - | - | 200 | 220 | 240 | 200 | 220 | 240 |
| Automated Passenger Counting System | X | X | X | | | | - | - | - | 70 | 500 | 560 | 620 | 570 | 630 | 690 |
| Smart Card System | X | | | | | | 100 | 140 | 170 | 30 | 90 | 100 | 110 | 220 | 270 | 310 |
| On-Board Transit Safety Systems | X | X | X | | | | - | - | - | 930 | 1,130 | 1,260 | 1,390 | 2,060 | 2,190 | 2,320 |
| Traffic Signal Priority for Transit | X | | | | | | - | - | - | 110 | 190 | 230 | 280 | 300 | 340 | 390 |
| Automatic Vehicle Identification | X | X | X | X | | | 190 | 210 | 230 | 680 | 2,920 | 3,270 | 3,640 | 3,790 | 4,160 | 4,550 |
| Transit Traveler Information | X | X | X | | | | 170 | 200 | 220 | 750 | 1,020 | 1,640 | 2,410 | 1,940 | 2,590 | 3,380 |
| Parking Management and Information System | X | X | X | | | | 230 | 240 | 260 | 2,830 | 3,390 | 4,100 | 4,890 | 6,450 | 7,170 | 7,980 |
| Dynamic Ridesharing/Paratransit Service | | X | X | | | | - | - | - | 80 | 3,380 | 3,760 | 4,140 | 3,460 | 3,840 | 4,220 |
| RV Park & Ride Lots with Surveillance | X | X | X | | | | 130 | 160 | 180 | 2,830 | 1,930 | 2,330 | 2,710 | 4,890 | 5,320 | 5,720 |

**Table 4-4:** Estimated Per Device Operations and Maintenance Costs.

| Device | Electrical | Hardware | Software | Radio | Testing | Fiber Optics | Power & Telephone Low | Power & Telephone Average | Power & Telephone High | Spares & Replace-ments | Maintenance Sub-Total Low | Maintenance Sub-Total Average | Maintenance Sub-Total High | Total Low | Total Average | Total High |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Infrastructure Operations and Maintenance** | | | | | | | | | | | | | | | | |
| Automatic Traffic Rec's/Traffic Monitor Station | X | | X | | | | $ 180 | $ 200 | $ 220 | $ 290 | $2,140 | $2,450 | $2,820 | $2,610 | $2,940 | $3,330 |
| Video Detectors | X | | | | | | 150 | 170 | 190 | 2,500 | 700 | 850 | 1,030 | 3,350 | 3,520 | 3,720 |
| Closed-Circuit Television (CCTV) Surveillance | X | X | | | | | 230 | 260 | 280 | 3,580 | 1,390 | 1,660 | 1,940 | 5,200 | 5,500 | 5,800 |
| Road and Weather Information Systems | X | X | X | | | | 210 | 230 | 250 | 2,150 | 3,760 | 4,490 | 5,190 | 6,120 | 6,870 | 7,590 |
| Travel Time Estimation | X | X | X | | | | 170 | 200 | 220 | 830 | 2,470 | 2,860 | 3,300 | 3,470 | 3,890 | 4,350 |
| Highway Travel Conditions Reporting System | | X | X | | | | - | - | - | - | 31,150 | 34,610 | 38,070 | 31,150 | 34,610 | 38,070 |
| Regional Server/Coordination Software | | X | X | | | | - | - | - | - | 3,150 | 3,500 | 3,850 | 3,150 | 3,500 | 3,850 |
| Satellite Traffic Operations Center | X | X | | X | | | - | - | - | - | 12,170 | 13,520 | 14,870 | 12,170 | 13,520 | 14,870 |
| **Fleet Operations and Maintenance** | | | | | | | | | | | | | | | | |
| Fleet Monitoring | X | X | X | X | | | $ 40 | $ 40 | $ 40 | $ 150 | $ 160 | $ 180 | $ 200 | $ 350 | $ 370 | $ 390 |
| Probe Vehicle Instrumentation | X | X | X | X | | | 40 | 40 | 40 | 180 | 170 | 190 | 210 | 390 | 410 | 430 |
| **Commercial Vehicle Operations** | | | | | | | | | | | | | | | | |
| Electronic AVI Preclearance | X | X | X | | | | $ 220 | $ 240 | $ 250 | $ 2,110 | $5,180 | $5,780 | $6,590 | $7,510 | $8,130 | $8,950 |
| Weigh-in-Motion | X | X | X | | | | 220 | 240 | 250 | 2,610 | 5,280 | 5,880 | 6,690 | 8,110 | 8,730 | 9,550 |
| Downhill Speed Advisory System | X | X | X | | | | 230 | 250 | 270 | 4,110 | 5,980 | 7,000 | 8,130 | 10,320 | 11,360 | 12,510 |
| Hazardous Materials Management | | X | X | | | | - | - | - | 80 | 3,320 | 3,690 | 4,060 | 3,400 | 3,770 | 4,140 |
| **Infrastructure Support** | | | | | | | | | | | | | | | | |
| Wireline Communications | | | | | | X | $ - | $ - | $ - | $ 200 | $ 470 | $ 530 | $ 700 | $ 670 | $ 730 | $ 900 |
| Wireless Communications | | | | X | | | - | - | - | 800 | 60 | 70 | 80 | 860 | 870 | 880 |
| Coordination Activities | | X | X | | | | - | - | - | 40 | 1,320 | 1,470 | 1,620 | 1,360 | 1,510 | 1,660 |

(1) Telephone costs will depend upon usage levels.

**Table 4-4:** Estimated Per Device Operations and Maintenance Costs. (cont.)

# 5 ORGANIZATIONAL AND INSTITUTIONAL ISSUES

As critical as technical issues are, it is also important to address the institutional and organizational issues that need to be considered in operating and maintaining the COATS study area's ITS infrastructure. Table 5-1 classifies some of the principal organizational and institutional issues into nine categories:

- operations,
- maintenance model,
- repair prioritization,
- preventative maintenance,
- resource allocation,
- contracting,
- training,
- budgeting, and
- interstate issues.

| Category | Issue | Questions to be Answered | Recommendations/Comments |
|---|---|---|---|
| Operations | TMC | • Where should TMCs be located?<br>• What role should the TMCs have?<br>• How do the TMCs interact with other organizational units? | • Skill sets for TMC operators need to be selected to match the desired role of the TMC<br>• Partnerships with other public-sector agencies as well as private-sector firms may help to offset TMC staffing and/or building needs |
| | Communications Networks | • Where is there a need for real-time wireline communications that does not currently exist?<br>• Can the agency justify building a communications network?<br>• Can the agency enter into a private sector partnership to use a network paid for by others? | • The communication needs should be determined through an architecture development process<br>• Some studies have shown that a combination of private- and public-sector ownership of the communications network is most cost-effective<br>• Ownership issues, especially relating to maintenance, should be resolved at the outset |
| | Vehicles | • How many vehicles should be allocated for ITS operations and maintenance support?<br>• Where should these vehicles be located? | • This will be determined as a result of deployment decisions |
| | Power | • Can multiple ITS devices be collocated in order to reduce the costs of running power to the site? | • Solar power may not be steady enough for many locations |
| Maintenance Model | Identifying Repairs | • How are maintenance needs identified?<br>• To whom is the repair need reported?<br>• Who is responsible for diagnosing the problem? | • "Push" technology – where the device reports failures to a TMC – is desirable<br>• Self-diagnostic technologies are also desirable<br>• Repair needs should be reported to a single person or phone number, from where the repair process may start<br>• To improve response time, it is desirable to have diagnostic capability geographically near to the device<br>• Roles need to be defined clearly at the beginning |

**Table 5-1:** Organizational and Institutional Issues.

| Category | Issue | Questions to be Answered | Recommendations/Comments |
| --- | --- | --- | --- |
| Maintenance Model (cont.) | Coordination and Tracking | • Will more than one unit or division be involved in the maintenance process?<br>• If so, who will coordinate their efforts to ensure the repair gets completed? | • ITS device components may need different skill backgrounds (computer, electronics, radio, etc.), which will necessitate access to staff having a mix of technical capabilities, or outsourcing of maintenance<br>• A single point-of-contact is recommended to coordinate activities across many organizational units<br>• There needs to be buy-in to the process throughout the various organizational units |
| | Performing Repairs | • Which individuals or organizational units will be involved in the repair?<br>• At what point are these individuals brought in?<br>• Where should staff who are involved in the maintenance process be located? | • For each organizational unit involved in the repair process, a single point-of-contact within that unit is recommended<br>• Input from key stakeholders should determine who should be brought in and when<br>• There should be some basic diagnostic and repair capability located at each of the regions, in order to minimize downtime<br>• High-priority devices should have modular components, in order to minimize downtime |
| | Testing Repair | • Who is responsible for testing the repair to ensure that the device is working satisfactorily? | • Agencies need to perform testing of maintenance even when vendors or contractors perform repair for purposes of quality assurance |
| | Logging | • Who is responsible for logging maintenance activity?<br>• What system should be used for logging maintenance activity? | • The single point-of-contact would logically record maintenance activity<br>• The logging system should be common in structure and accessible to others in the agency and to partnering agencies |
| | Roles and Responsibilities | • What are the maintenance roles and responsibilities for each unit in the organization?<br>• Who reports to whom? | • Outreach to each organizational unit is critical to ensure that there is consensus and buy-in about roles and responsibilities |

**Table 5-1:** Organizational and Institutional Issues. (cont.)

| Category | Issue | Questions to be Answered | Recommendations/Comments |
|---|---|---|---|
| Repair Prioritization Guidelines | Development | • How should guidelines be developed for prioritizing repairs?<br>• How are guidelines that are in conflict between regions to be resolved? | • Priority guidelines should reflect regional needs<br>• Guidelines should be based not solely on device technology (e.g. is it a variable message sign?), but on device function (e.g. does it primarily improve safety?)<br>• Guidelines need to be coordinated across regions as well, especially for extra-regional devices (like the Internet) |
| | Enforcement | • How are prioritization guidelines enforced? Where in the organization does this decision come into play? | • Guidelines should specify a desired response time between when a device goes down and when it is brought back to full operations<br>• Guidelines should be published<br>• Guidelines will likely need to have some flexibility to reflect unforeseeable circumstances<br>• For priority devices, it may be necessary to have people on-call from each key organizational unit to ensure that repairs can be completed as needed |
| Preventative Maintenance | | • What are appropriate preventative maintenance recommendations?<br>• What skill sets are required to perform preventative maintenance?<br>• How can it be assured that preventative maintenance will occur? | • Manufacturers and some ITS maintenance plans have guidelines for appropriate preventative maintenance<br>• Checklists should be developed for ensuring preventative maintenance tasks are performed adequately<br>• This may be a good activity to contract because it is not time-critical and may use a more diluted skill set |
| Resource Allocation | Maintenance Staffing Needs | • What staffing resources with what skill base are required to perform maintenance? | • Staffing needs should be estimated at a per-device level<br>• Staff time needs to reflect travel time to access devices, as well as time for regular training and professional development |
| | Operations Staffing Needs | • What staffing resources with what skill base are required for each region? | • Estimates for operations staffing needs will reflect what functions are desired to occur at each TMC |

**Table 5-1:** Organizational and Institutional Issues. (cont.)

| Category | Issue | Questions to be Answered | Recommendations/Comments |
|---|---|---|---|
| Resource Allocation (cont.) | Other Needs | • How many of what kind of spare parts should be acquired for each device?<br>• How should resources be allocated for emergency device failures? | • Spare parts inventories should reflect vendor recommendations<br>• Standardization of devices, through sole-source vendor relationships or tight procurement specifications, can reduce inventory needs as well as training needs<br>• Spare parts should be acquired in advance, perhaps as part of original device procurement, in order to minimize downtime<br>• A centralized budget is recommended for paying for unexpected replacement of devices |
| | Staffing Availability | • What staffing resources at what skill level are currently available for performing ITS maintenance? | • Review job descriptions of key staff members to identify how much time they are allocated to have |
| | Resource Gaps | • To what extent should contracting be used to close gaps in staffing and/or skill levels?<br>• To what extent may additional staffing or training resources be used to close gaps?<br>• Who decides how staffing and/or training gaps will be addressed? | • Contracting may not be a viable option in some areas due to the availability of service<br>• Adding staff may not be a viable or desirable option due to political reasons<br>• Having technicians capable of making repairs in multiple disciplines is an asset in a rural context |
| Contracting | Area of responsibility | • Which devices, if any, would appropriate to contract for maintenance?<br>• Which maintenance tasks (such as preventative maintenance) would be appropriate to contract? | • To promote economies of scale, these decisions should be made for geographic areas with a significant level of deployment |
| | Terms | • What should be the contract duration?<br>• What performance specifications should be included in the contract? | • Two-year contracts with renewal options are fairly common for ITS maintenance<br>• Response time is a common performance measure<br>• Performance specifications may be difficult to enforce |
| | Administration | • Who manages contracts?<br>• What type of contracting should be used (e.g. cost-plus, fixed fee, etc.)? | • It helps to promote achievement of performance specifications by having contract administrators have some involvement in ITS operations as well |

**Table 5-1:** Organizational and Institutional Issues. (cont.)

| Category | Issue | Questions to be Answered | Recommendations/Comments |
|---|---|---|---|
| Training | | • What are areas where training of maintenance staff should be improved to better address ITS maintenance?<br>• How do maintenance staff obtain training on new technologies? | • Training gaps are best closed by obtaining comprehensive training when a device is deployed and by having technicians train each other as time goes on<br>• Training should focus on areas where there is a current training deficit<br>• Maintenance manuals should be acquired and kept for all field deployments in areas accessible to maintenance personnel |
| Budgeting | Accounting | • How should operations and maintenance costs be allocated? | • Ideally on a per-device basis, to improve planning |
| | Procurement | • Can the budgeting process be structured to reflect operation and maintenance costs? | • Agencies may be seek to apply life-cycle costs into the procurement process |
| Interstate Issues | Maintenance Model | • How does a single point-of-contact coordinate maintenance activities across the state boundary, should it become necessary?<br>• How can repairs be resolved effectively near the state line? | • Stakeholder outreach and education across the state line is critical<br>• Develop memorandum of understanding between Caltrans and ODOT to address issues beforehand<br>• Inter-jurisdictional cooperation and coordination is necessary to improve response time<br>• Applications near state lines should not any affect on allocation of operational costs (i.e. power and telephone) |
| | Maintenance Prioritization | • How are guidelines enforced and coordinated across the state line? | |
| | Resources | • How may staffing resources be shared across the state line? | |

**Table 5-1:** Organizational and Institutional Issues. (cont.)

## 6 SUMMARY AND NEXT STEPS

In planning intelligent transportation systems deployment, operations and maintenance considerations typically receive inadequate attention. This guidance document has served to provide some assistance in planning for the future operations and maintenance needs associated with ITS technologies that may be deployed as part of the COATS project. It described the types of operations costs typically encountered in ITS deployments. This document then reviewed the maintenance needs on a device-by-device basis for candidate technologies in the COATS study area. After developing some budgetary estimates for recurring operations and maintenance costs associated with each device, this document described some of the critical organizational and institutional issues that need to be resolved for maintenance to be done effectively and efficiently.

While this document provides significant progress in estimating likely operations and maintenance costs associated with various ITS technologies, there are several areas where cost estimates are lacking. These costs will depend upon the structure and location of TMCs, as well as pending decisions regarding staffing, vehicle costs, and supporting communications infrastructure. As decisions are made in these regards, it will help to refine the estimates produced in this report to provide a more realistic estimate of true operations and maintenance costs.

This document has also provided guidance regarding organizational and institutional issues that are likely to be faced in operations and maintenance of ITS in the bi-state area. As the COATS project transitions from a planning effort to a deployment effort, these issues will need to be addressed by Caltrans and ODOT in order to maximize the effectiveness and longevity of COATS-related infrastructure.

## REFERENCES


1. Chris Strong, Robb Larson and Alan McAllister, *Intelligent Transportation Systems Maintenance Plan*, two volumes, Western Transportation Institute, Montana State University-Bozeman, December 1999.
2. U.S. Department of Transportation, *Advanced Rural Transportation Systems (ARTS) Strategic Plan*, U.S. Department of Transportation, Washington [DC], August 1997.
3. Allen Tel Communications, Telephone Conversation, September 27, 1999.
4. *The Pennsylvania Turnpike Commission's Incident Management Team*, Pennsylvania Turnpike Commission, 1993.
5. Enterprise Program, Variable Speed Limit Signs, http://www.enterprise.prog.org/varspeed.htm, accessed October 13, 1999.
6. Coastal Environmental Systems, Variable Speed Limit Signs, http://www.coastalenvironmental.com/rwis/roadspeed.html, accessed October 13, 1999.
7. Zarean, M., E.N. Williams, B.A. Leonard, and R. Sivarandan, *Rural Applications of Advanced Traveler Information Systems: User Needs and Technology Assessment*, FHWA-RD-97-034, Federal Highway Administration, McLean [VA]: 1997.
8. Roosevelt, Daniel S. (RooseveltDS@vdot.state.va.us), "RE: More information about Bridge Deck Anti-Icing System", E-Mail to Chris Strong (ChrisS@coe.montana.edu), February 8, 2000.
9. Marchant, Jack, TMC Analyst, Region 1 TMOC, Oregon Department of Transportation, Telephone Conversation, August 27, 1999.
10. Minnesota Department of Transportation, Integrated Corridor Traffic Management System, http://www.dot.state.mn.us/tmc/special/ictm.html, Accessed October 13, 1999.
11. "Overview of the Traffic Channel," ITS UW Web Site, http://www.its.washington.edu/trafchan/overview.html. Accessed January 24, 2000.
12. "TripCheck - Oregon Department of Transportation," http://www.tripcheck.com. Accessed January 25, 2000.
13. Farmer, Bill, Department of Administrative Services, Telephone Conversation, September 9, 1999.
14. McCormick Rankin Consulting Engineers, *Technology Evaluation for Changeable Message Signs*, Ontario Ministry of Transportation, Toronto: 1989.
15. Institute of Transportation Engineers, *Traffic Control Systems Handbook*, Institute of Transportation Engineers, Washington [DC]: 1985.
16. Ingham, Fred, Skyline Products Inc., Telephone Conversation, October 25, 1999.
17. Upchurch, Jonathan E., Hadi Baaj, Jeffrey D. Armstrong and Gary B. Thomas, *Evaluation of Variable Message Signs*, Center for Advanced Research in Transportation, Tempe [AZ]: 1991.
18. Pearson, Eric, Vultron Inc., Telephone Conversation, September 24, 1999.
19. Hanson, Kevin, American Electronic Sign, Telephone Conversation, September 24, 1999.
20. Smith, Brian L., Catherine C. McGhee, Bruce R. Newman, Steven L. Jones, and Amy A. O'Leary, *An Investigation of Operational Procedures for Highway Advisory Radio Systems*, Report No. VTRC 96-R4, Virginia Transportation Research Council, Charlottesville [VA]: 1995.

21. Casey, Robert et al, Advanced Public Transportation Systems: The State of the Art Update '98, prepared for the Federal Transit Administration, U.S. Department of Transportation, Washington [DC]: 1998.
22. Body, Chris, Orbital Sciences Corporation, Telephone conversation, October 5, 1999.
23. Kennedy, Jim, Pearpoint Inc., Telephone conversation, October 1, 1999.
24. Larson, Chuck (Norman.C.LARSON@odot.state.or.us), "Re: Highway Travel Conditions Reporting System", E-Mail to Chris Strong (ChrisS@coe.montana.edu), July 6, 1999.
25. Wittenberg, James, Oregon Department of Transportation and Steve White, Oregon State Police, Telephone conversation, October 21, 1999.
26. Jackson, Mike, Iowa Department of Transportation, Telephone conversation, October 14, 1999.
27. Bergen, A.T., Brian W. Taylor, Rob Bushman and Nancy Pon, "Keep on trucking: Safer commercial traffic with ITS," *Traffic Technology International*, Annual Review '98, pp. 239-242.
28. "Leotek Electronics USA Corp. – Traffic Specs." http://www.leotek.com/tfcspec.htm. Accessed February 10, 2000.
29. "8-inch Traffic Light Specs – Act One" http://www.actone1.com/LEDs/Traffic/8___specs/8___specs.html. Accessed February 10, 2000.
30. "Ecolux Product 2 Data Sheet" http://www.ecolux.qc.ca/prod02.htm. Accessed February 10, 2000.
31. "Signal Communications – User Powered Call Box," http://www.sigcom.com/product/up.html. Accessed February 22, 2000.
32. "170 E Microcomputer – Control Technologies of Central Florida, Inc.," http://www.cttraffic.com/sx020001.htm. Accessed February 23, 2000.
33. "Type 170 Controller – Eagle TCS" http://www.eagletcs.com/prodsandservices/controls/type170e.htm. Accessed February 23, 2000.
34. "Model 170E Microcomputer – Safetran Traffic Systems" http://www.safetran-traffic.com/products/170e.htm. Accessed February 23, 2000.
35. "Telenetics Cell Modem" http://www.arcelect.com/Telenetics_Cellular_Modem.htm. Accessed February 22, 2000.
36. Surface Systems Inc., "SCAN Detector Specifications Sheet," no date.
37. "Appliance Typical Power Consumption Information – OK Solar," http://www.oksolar.com/info/consumption.html. Accessed February 18, 2000.
38. "Power, Energy and Solar Electricity – Sunelco," http://www.sunelco.com/page7.html. Accessed February 22, 2000.
39. "Alfia Services Limited – Barriers & Industrial," http://www.alfia.co.uk/alfia/p-barr.shtml. Accessed March 9, 2000.
40. "B8 Barrier Gate – Sytron," http://www.sytron.com/b8_barrier_gate.htm. Accessed March 9, 2000.
41. "Sensors – Earthquake Safety Systems, Inc." http://www.eqsafetysys.com/sensors.htm. Accessed March 9, 2000.
42. "TOMAR Electronics, Inc. – STROBECOM II Optical Preemption Detectors," http://www.tomar.com/products/section1/p092.htm. Accessed February 10, 2000.

43. "License Plate Capture Systems by PearPoint," http://www.pearpoint.com/traffic.html. Accessed February 18, 2000.
44. "Highway Advisory Radio – Control Technologies of Central Florida, Inc.," http://www.cttraffic.com/sx110003.htm. Accessed February 18, 2000.
45. Information Station Specialists, "ITS6000: The Highway Advisory Radio Network," no date.
46. Iteris Inc., "Vantage One Product Sheet," Revised January 2000.
47. "Traficon: Hardware Description of the VIP (Video Image Processing) Board," http://www.traficon.be/hardware.htm. Accessed February 22, 2000.
48. Panasonic Corporation, "WV-CST604 Color Extended Range Unitized Surveillance Device With Presets: Product Features," no date.
49. Sensormatic Electronics Corporation, "American Dynamics Video Surveillance Systems: DeltaDome Programmable Dome Cameras," September 1998.
50. Panasonic, "AG-RT600A Real Motion Time-Lapse Video Cassette Recorder Product Features," no date.
51. Panasonic, "AG-6540 VHS Time-Lapse Video Cassette Recorder," no date.
52. Diamond Electronics, "Real Time Event Recorder Features Sheet," August 1996.
53. "SmartCard Products, Components, Specifications – UniVision," http://www.uvel.com/html/body_sSpec.htm. Accessed March 15, 2000.
54. TagMaster AB, "S1501 PassMan Reader Product Sheet," November 1999.
55. Pacific Power & Light Company, Oregon Schedule 25: General Service, December 3, 1999.
56. Pacific Power & Light Company, California Schedule A-25: General Service Less than 20 kW, January 27, 1999.
57. Pacific Power & Light Company, California Schedule A-32: General Service 20kW and Over, January 27, 1999.
58. Pacific Gas & Electric Company, Schedule A-1: Small General Service, April 21, 1999.
59. "Commercial & Industrial Rates – Columbia River Public Utility District," http://www2.crpud.net/business/rates.asp, Accessed March 6, 2000.
60. "Rates for MEC – Midstate Electric Cooperative," http://www.midstatecoop.com/rates.htm. Accessed February 7, 2000.
61. Haas, Kevin (Kevin.J.HAAS@odot.state.or.us), "Re: Utility Costs," E-Mail to Chris Strong (ChrisS@coe.montana.edu), February 11, 2000.
62. "Products and Services Description – FasTrak Frame Relay – Pacific Bell," http://www.pacbell.com/Products_Services/Business/ProdInfo_1/1,1074,133-1-0,00.html. Accessed March 14, 2000.
63. "Rate Planner – Roseville Communications Company," http://www.rtcnet.com/prod/rateplanner.html. Accessed March 14, 2000.
64. "Schedule A-1 page 1 – California-Oregon Telephone Company," http://www.cot.net/schedule_a-1_page_1.html. Accessed March 14, 2000.
65. "Beaver Creek Cooperative Telephone Company," http://www.bctonline.com/services/telephone/. Accessed March 14, 2000.

# APPENDIX A PREVENTATIVE MAINTENANCE TABLES

| Device | Component | Maintenance Procedure | Frequency |
|---|---|---|---|
| **Traveler Safety and Security** | | | |
| Mayday Callboxes | Telephone handsets | Test equipment | Every month |
| Cellular Call-in | Roadside signs (1) | Prune vegetation | Every 12 months |
| | Cellular towers | Various power and frequency tests | (2) |
| Computer-Aided Dispatch (CAD) | CAD Server | Various computer maintenance activities | (2) |
| | CAD workstations | Re-booting, testing and upgrades | Every month |
| | Communications within TOC | Inspect, check connections and cabling | Every 12 months |
| | Software | Install upgrades | As available |
| | Database management | Various database management activities | (2) |
| Queue Detection System | Controller/Timer | Check batteries, test induction, check connections | Every 6 months |
| | Loops | Visual inspection and testing | Every 3 months |
| | Local cable and wiring | Inspect | Every 12 months |
| | Flashing beacon/sign | Visual inspection and testing | Every 12 months |
| | Cabinet | Visual inspection and cleaning | Every 12 months |
| Intersection Advance Warning Signing | Controller | Check batteries, test induction, check connections | Every 6 months |
| | Loops | Visual inspection and testing | Every 3 months |
| | Local cable and wiring | Inspect | Every 12 months |
| | Flashing beacon/sign | Visual inspection and testing | Every 12 months |
| | Cabinet | Visual inspection and cleaning | Every 12 months |
| Intersection-Based Incident Detection System | Loops | Visual inspection and testing | Every 3 months |
| | Controller/RPU | Re-boot; visual inspection | Every 2 months |
| | Software/firmware | Install upgrades | As available |
| Advanced Bicycle/Pedestrian Warning | Push button | Test connection | Every 3 months |
| | Controller | Check batteries, test induction, check connections | Every 6 months |
| | Local cable and wiring | Inspect | Every 12 months |
| | Flashing beacon/sign | Visual inspection and testing | Every 12 months |
| Dynamic Warning Variable Message Signing | Sensors | Visual inspection; cleaning and calibration | Every 12 months |
| | Flashing beacon and sign | Visual inspection and testing | Every 6 months |
| | Field controller | Visual inspection and testing | Every 2 months |
| | Controller cabinet | Visual inspection and cleaning | Every 12 months |
| | Software | Install upgrades | As available |
| | Communications equipment | Visual inspection; check connections | Every 12 months |

| Device | | Component | Maintenance Procedure | Frequency |
|---|---|---|---|---|
| **Traveler Safety and Security (cont.)** | | | | |
| Variable Speed Limit Signs (VSLS) | | Sensors | Visual inspection; cleaning and calibration | Every 12 months |
| | | Variable message sign | See Permanent Variable Message Sign (below) | |
| | | Field controller | Visual inspection and testing | Every 2 months |
| | | Controller cabinet | Visual inspection and cleaning | Every 12 months |
| | | Software | Install upgrades | As available |
| | | Communications equipment | Visual inspection; check connections | Every 12 months |
| Automatic Anti-Icing System for Roads and Bridges | 1 | Pavement sensors | Cleaning and calibration | Every 12 months |
| | 1 | Controller | Visual inspection and testing | Every 2 months |
| | 1 | Local cable and wiring | Inspect | Every 12 months |
| | 1 | Software | Install upgrades | As available |
| | 1 | Flashing beacon and sign | Visual inspection and testing; bulb replacement | Every 12 months |
| | 1 | Chemical dispenser | Clean nozzles; replenish fluids | Twice per winter |
| | 2 | Pavement sensors | Cleaning and calibration | Every 12 months |
| | 2 | Controller | Visual inspection and testing | Every 2 months |
| | 2 | Local cable and wiring | Inspect | Every 12 months |
| | 2 | Software | Install upgrades | As available |
| | 2 | Flashing beacon and sign | Visual inspection and testing; bulb replacement | Every 12 months |
| | 2 | Heating element | Test | Once per winter |
| Advance Warning Systems for Narrow Lane Widths | | Vehicle height and width detectors | Test signal level and lead cable; calibrate | Every 6 months |
| | | Loops | Visual inspection and testing | Every 3 months |
| | | Controller | Visual inspection and testing | Every 6 months |
| | | Local cable and wiring | Inspect | Every 12 months |
| | | Flashing beacon and sign | Visual inspection and testing; bulb replacement | Every 12 months |
| Automated Flood Warning | | Water level sensor | Cleaning and calibration | Every 12 months |
| | | Controller | Visual inspection and testing | Every 2 months |
| | | Communications equipment | Visual inspection; check connections | Every 12 months |
| | | Flashing beacon and sign | Visual inspection and testing; bulb replacement | Every 12 months |

| Device | Component | Maintenance Procedure | Frequency |
|---|---|---|---|
| **Traveler Safety and Security (cont.)** | | | |
| Automated Gate Closure System | Seismic sensor | Visual inspection and calibration | Every 12 months |
| | Controller | Visual inspection and testing | Every 2 months |
| | Communications equipment | Visual inspection; check connections | Every 12 months |
| | Software | Install upgrades | As available |
| | Gate arm | Visual inspection and testing | Every 12 months |
| Mayday Systems | Server | Re-boot; server management activities | Every week |
| | Software | Install upgrades | As available |
| **Emergency Services** | | | |
| Traffic Signal Preemption for Emergency Vehicles | In-vehicle unit (1) | Testing | Every 12 months |
| | Optical reader | Visual inspection and testing | Every 6 months |
| Incident Response Vehicles | AVL software | Install upgrades | As available |
| | AVL server | Database and server management activities | Every week |
| | In-vehicle radio units | Inspection and testing | Every 12 months |
| | On-board VMS | Visual inspection and cleaning; testing | Every 6 months |
| | Vehicle maintenance | Based on mileage, manufacturer's recommendations | (1) |
| Pre-Planned Detour Routes | Route selection | Test route selection algorithms in each region | Every 12 months |
| **Tourism and Traveler Information Services** | | | |
| Alphanumeric Paging | Software | Install upgrades | As available |
| 1-800 Number | Cable in call center | Inspect, check connections and cabling | Every 12 months |
| | Software (voice generation) | Install upgrades | As available |
| | Software (phone server) | Upgrades and enhancements | As available |
| | Servers | Re-boot; server management and database activities | Every week |
| Television | Server | Re-boot; server management and database activities | Every week |
| Internet access | Web server | Re-boot; server management activities | Every week |
| Kiosks | Terminals | Inspect; clean monitors and cabinets | Every month |
| | Network connections | Check connections, replace cabling | Every 12 months |
| | Thermal printers | Check print quality; replace paper | Every month |
| | Software (Kiosk-level) | Install upgrades | As available |
| | Software (Server-level) | Install upgrades | As available |
| | Kiosk server | Re-boot; server management and database activities | Every week |

| Device | | Component | Maintenance Procedure | Frequency |
|---|---|---|---|---|
| **Tourism and Traveler Information Services (cont.)** | | | | |
| Changeable Message Signs (CMS) (1) | | Controller/Motor | Visual inspection and testing | Every 12 months |
| | | Sign Display | Testing, cleaning; check illumination | Every 12 months |
| | | Communications | Check modems and hardwire connections; check radio-activated connections | Every 12 months |
| Permanent Variable Message Signs (VMS) | | Controller/Internal Wiring | Visual inspection and testing | Every 6 months |
| | | Sign Matrix, Panels, Modules | Testing and cleaning; replace bulbs and pixels as necessary | Every 6 months |
| | | Sign Housing | Visual inspection and check connections; clean filters | Every 6 months |
| | | Modem/Communications | Visual inspection; check connections; test messages | Every 12 months |
| | | Software | Install upgrades | As available |
| | | Surge Protection/Power | Visual inspection and testing | Every 6 months |
| Portable Variable Message Signs (VMS) | | Controller/Internal Wiring | Visual inspection and testing | Every 3 months |
| | | Sign Matrix, Panels, Modules | Testing and cleaning; replace bulbs and pixels as necessary | Every 3 months |
| | | Sign Housing | Visual inspection and check connections; clean filters | Every 3 months |
| | | Software | Install upgrades | As available |
| | | Power | Visual inspection and testing; check and replace batteries as necessary | Every 3 months |
| Work Zone Delay Advisory System | 1 | Flashing Beacon/ Controller | Visual inspection and testing | Every 12 months |
| | | Local Cable and Wiring | Inspect | Every 12 months |
| | 2 | Loop Detectors | Visual inspection and testing | Every 12 months |
| | | Local Cable and Wiring | Inspect | Every 12 months |
| | | Controller | Check batteries; visual inspection and cleaning; check connections | Every 12 months |
| | | Software | Install upgrades | As available |
| | | Variable Message Sign | See Permanent Variable Message Sign (above) | |
| | 3 | License Plate Readers | See Travel Time Estimation (below) | |
| | | Travel Time Server | See Travel Time Estimation (below) | |
| | | Local Communications | Inspect | Every 6 months |
| | | Variable Message Sign | See Permanent Variable Message Sign (above) | |

| Device | Component | Maintenance Procedure | Frequency |
| --- | --- | --- | --- |
| **Tourism and Traveler Information Services (cont.)** | | | |
| Highway Advisory Radio (HAR) | Antenna Assembly | Visual inspection | Every 6 months |
| | Transmitter | Check power and range and frequency | Every 6 months |
| | Beacon Equipment | Visual inspection and testing | Every 6 months |
| | Recorder/Player Unit | Testing; check connections | Every 6 months |
| | Operator Workstation | Basic computer maintenance; test messages | Every 6 months |
| | Power Supply | Check power level and connections | Every 6 months |
| **Public Traveler/Mobility Services** | | | |
| Automatic Vehicle Location (AVL) | Vehicle Sensors | Inspection, calibration and cleaning | Every 12 months |
| | AVL Software | Install upgrades | As available |
| | AVL Server | Database and server management activities | Every week |
| Transit Vehicle Routing, Scheduling and Tracking Software | Software | Install upgrades | As available |
| Automated Passenger Counting System | Infrared Sensors / Pressure Mats | Clean, test and calibrate as necessary | Every 12 months |
| | On-board Computer | Routine re-booting | Every 2 months |
| | Software | Install upgrades | As available |
| Smart Card System | Readers | Inspection and cleaning | Every 12 months |
| On-Board Transit Safety Systems | Surveillance Camera | See Closed-Circuit Television Surveillance (below) | |
| | Modems/ Communications | Visual inspection and testing of both in-vehicle and extra-vehicle systems | Every 12 months |
| | In-vehicle Computer | Re-boot, visual inspection and diagnostics | Every 2 months |
| | Software (center) | Install upgrades | As necessary |
| | Software (vehicle) | Install upgrades | As necessary |
| | Security Server | Re-boot, prune and store records | Every week |
| | Alarm Buttons | Test and lubricate (if necessary) | Every 12 months |
| | Dashboard Display | Test and clean | Every 12 months |
| Preferential Signal Treatment for Transit | In-vehicle Unit (1) | Testing | Every 12 months |
| | Optical Reader | Visual inspection and testing | Every 6 months |

| Device | Component | Maintenance Procedure | Frequency |
|---|---|---|---|
| **Public Traveler/Mobility Services (cont.)** | | | |
| Automatic Vehicle Identification | Readers | Visual inspection and calibration | Every 6 months |
| | In-vehicle Unit | Testing | Every 12 months |
| | Port of Entry Computer | Re-boot; perform system diagnostics | Every 2 months |
| | Software (Port) | Install upgrades | As available |
| | Software (Server) | Install upgrades | As available |
| | AVI Server | Re-boot, prune and store records | Every week |
| | Red/green Light | Testing, bulb replacement | Every 12 months |
| Transit Traveler Information | Modems/ Communications | Visual inspection, testing | Every 12 months |
| | Software (Center) | Install upgrades as necessary | As available |
| | Variable Message Signs | See Permanent Variable Message Sign (below) | |
| Parking Management and Information System | Loop Detectors | Visual inspection and testing | Every 3 months |
| | Modems/Remote Communications | Visual inspection, testing | Every 12 months |
| | Local Cable and Wiring | Inspect | Every 12 months |
| | Controller | Inspect; check connections; test calibration; clean | Every 6 months |
| | Server | Re-boot; clean records | Every week |
| | Software (Server) | Install upgrades | As available |
| | Variable Message Signs | See Portable Variable Message Sign (below) | |
| Dynamic Ridesharing / Paratransit Service | Modems / Routers | Visual inspection, check connections | Every 12 months |
| | Software (Server) | Install upgrades | As available |
| | Server | Re-boot; clean records | Every week |
| Recreational Vehicle Park & Ride Lots with Surveillance | Surveillance Cameras | See Closed-Circuit Television Surveillance (below) | |
| | Modems/ Communications | Visual inspection, check connections | Every 12 months |
| | Center Software | Install upgrades | As necessary |
| | Video Switching Equipment | Clean, check connections, test all permutations | Every 6 months |
| | Camera Server | Re-boot; purge records | Every week |
| **Infrastructure Operations and Maintenance** | | | |
| Automatic Traffic Recorders | Controller | Check batteries; visual inspection and cleaning; check connections | Every 6 months |
| | Loops | Visual inspection and testing | Every 3 months |
| | Local Cable and Wiring | Inspect | Every 12 months |
| | Polling Software | Upgrade | As necessary |
| | Cabinet | Visual inspection and cleaning | Every 12 months |

| Device | Component | Maintenance Procedure | Frequency |
|---|---|---|---|
| **Infrastructure Operations and Maintenance (cont.)** | | | |
| Video Detection Systems | Support Structure | Visual inspection | Every 12 months |
| | Video Detector | Clean lens; visual inspection; calibration | Every 12 months |
| | Controller | Check batteries; visual inspection and cleaning; check connections | Every 12 months |
| | Surge Protection/Power | Visual inspection and testing | Every 12 months |
| Closed-Circuit TV (CCTV) Surveillance | Support Structure | Visual inspection | Every 12 months |
| | Camera/Lens/Filter/ Pan-Tilt-Zoom | Clean lens; visual inspection; check enclosure pressure | Every 6 months |
| | Camera Housing/Cables | Cleaning and visual inspection; check connections | Every 6 months |
| | Camera Control Receiver | Check pan-tilt-zoom capability using laptop; check connections | Every 6 months |
| | Camera Servers and Modems | Visual inspection and check connections | Every 12 months |
| | Weather Equipment | Visual inspection and calibration | Every 12 months |
| | Surge Protection/Power | Visual inspection and testing | Every 6 months |
| | Video Processing Equipment | Visual inspection and testing; check connections | Every 6 months |
| | Camera Server Software | Install manufacturer upgrade | As available |
| | Camera Server | Database and server management activities | Every week |
| Road and Weather Information System (RWIS) | Sensors | Visual inspection; cleaning and calibration | Every 12 months |
| | Local Cable and Wiring | Visual inspection | Every 12 months |
| | RPU | Re-boot and visual inspection | Every 2 months |
| | Modems/Routers | Visual inspection; check connections | Every 12 months |
| | Software (SCAN & Database) | Install upgrades as available | As available |
| | Surge Protection/Power | Visual inspection and testing | Every 6 months |
| | Servers (Regional/ Statewide) | Database and server management activities | Every week |
| Travel Time Estimation | Camera/Light Source | Visual inspection; clean lens; test alignment | Every 6 months |
| | Modems | Visual inspection; check connections | Every 12 months |
| | Controller/RPU | Re-boot and visual inspection | Every 2 months |
| | Software (RPU) | Install upgrades | As available |
| | Cabinet | Visual inspection and cleaning | Every 12 months |
| | Travel Time Server | Database and server management activities | Every week |
| | Software (Server) | Install upgrades | As available |

| Device | Component | Maintenance Procedure | Frequency |
|---|---|---|---|
| **Infrastructure Operations and Maintenance (cont.)** | | | |
| Highway Travel Conditions Reporting System (HTCRS) | Database Management | Pruning and database management | Every week |
| Regional Server/ Coordination Software | Software | Upgrades and enhancements | As available |
| | ATMS Database | Database pruning and management | Every week |
| Satellite Traffic Operations Center | Radio Consoles | Test and adjust as necessary | Every 12 months |
| | Cable and Wiring | Inspection and check connections | Every 12 months |
| | Operator Workstations | Re-boot and upgrade; diagnostic tests | Every month |
| | ATMS Servers | Frequent re-booting and diagnostics | Every week |
| **Fleet Operations and Maintenance** | | | |
| Fleet Monitoring | In-vehicle Sensors | Inspection, calibration and cleaning | Every 12 months |
| | In-vehicle Units | Testing, replace batteries | Every 12 months |
| | AVL Software | Install upgrades | As available |
| | AVL Server | Database and server management activities | Every week |
| Probe Vehicle Instrumentation | In-vehicle Sensors | Inspection, calibration and cleaning | Every 12 months |
| | In-vehicle Units | Testing, replace batteries | Every 12 months |
| | AVL Software | Install upgrades | As available |
| | AVL Server | Database and server management activities | Every week |
| **Commercial Vehicle Operations** | | | |
| Electronic AVI Preclearance | Sensors (Axle, AVC, AVL, Loops) | Test signal level and lead cable; calibrate | Every 6 months |
| | Grout and Sealant | Visual inspection | Every 6 months |
| | Detector Housings and Cabinets | Visual inspection; test ventilation | Every 6 months |
| | Electronics, Power Supplies and Modems | Visual inspection; cleaning; testing | Every 6 months |
| | Modems/Routers | Visual inspection; check connections | Every 12 months |
| | Cables and Connectors | Visual inspection and testing | Every 12 months |
| | Red Light/Green Light | Visual inspection and testing | Every 12 months |

| Device | Component | Maintenance Procedure | Frequency |
|---|---|---|---|
| **Commercial Vehicle Operations (cont.)** | | | |
| Weigh-in-Motion (WIM) Stations | Sensors (Axle, AVC, AVL, Loops) | Test signal level and lead cable; calibrate | Every 6 months |
| | Single Load Cell Scales | Test signal level and lead cable; calibrate | Every 6 months |
| | Piezoelectric Sensors | Test signal level and lead cable; calibrate | Every 6 months |
| | Grout and Sealant | Visual inspection | Every 6 months |
| | Detector Housings and Cabinets | Visual inspection; test ventilation | Every 6 months |
| | WIM Electronics, Power Supplies and Modems | Visual inspection; cleaning; testing | Every 6 months |
| | Modems/Routers | Visual inspection; check connections | Every 12 months |
| | Cables and Connectors | Visual inspection and testing | Every 12 months |
| | Red Light/Green Light | Visual inspection and testing | Every 12 months |
| Downhill Speed Advisory System | WIM Equipment | See guidelines under Weigh-in-Motion systems | |
| | VMS Equipment | See guidelines under Permanent Variable Message Signs | |
| Hazardous Material Response | Modems/Routers | Visual inspection, check connections | Every 12 months |
| | Software (Database) | Install upgrades | As available |
| | HazMat Server | Server and database management activities | Every week |
| **Infrastructure Support** | | | |
| Wireline Communications (i.e. fiber optic cable) | Landline Cable | Perform optical time domain reflectometer tests | Every 24 months |
| Wireless Communications (i.e. radio, cellular communications) | Hand-held Units | Visual inspection; testing | Every 12 months |
| | Radio Consoles | Visual inspection; testing | Every 12 months |
| Coordination Activities | Laptop Computers | Visual inspection; re-boot and diagnostics | Every month |
| | Tracking Software | Install upgrades | As available |

Notes
(1) Maintenance procedures are already in place.
(2) Maintenance responsibility is outside of DOT responsibility.