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16. ABSTRACT

Advanced Traveler Information Systems (ATIS) provide dynamic safety, delay and other information to travelers to help plan their trip (pre-trip) as well as during their trip (on route). The dissemination of traveler information is typically done through internet, cellular phones, telephones, kiosks, television, radio, in-vehicle systems, and fixed road-side ITS (Intelligent Transportation Systems) elements such as changeable message signs, highway advisory radio, etc.

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Portable Advanced Traveler Information Systems (Portable ATIS)

T.O. 1023

Concept of Operations

Prepared for

California Department of Transportation

Prepared by

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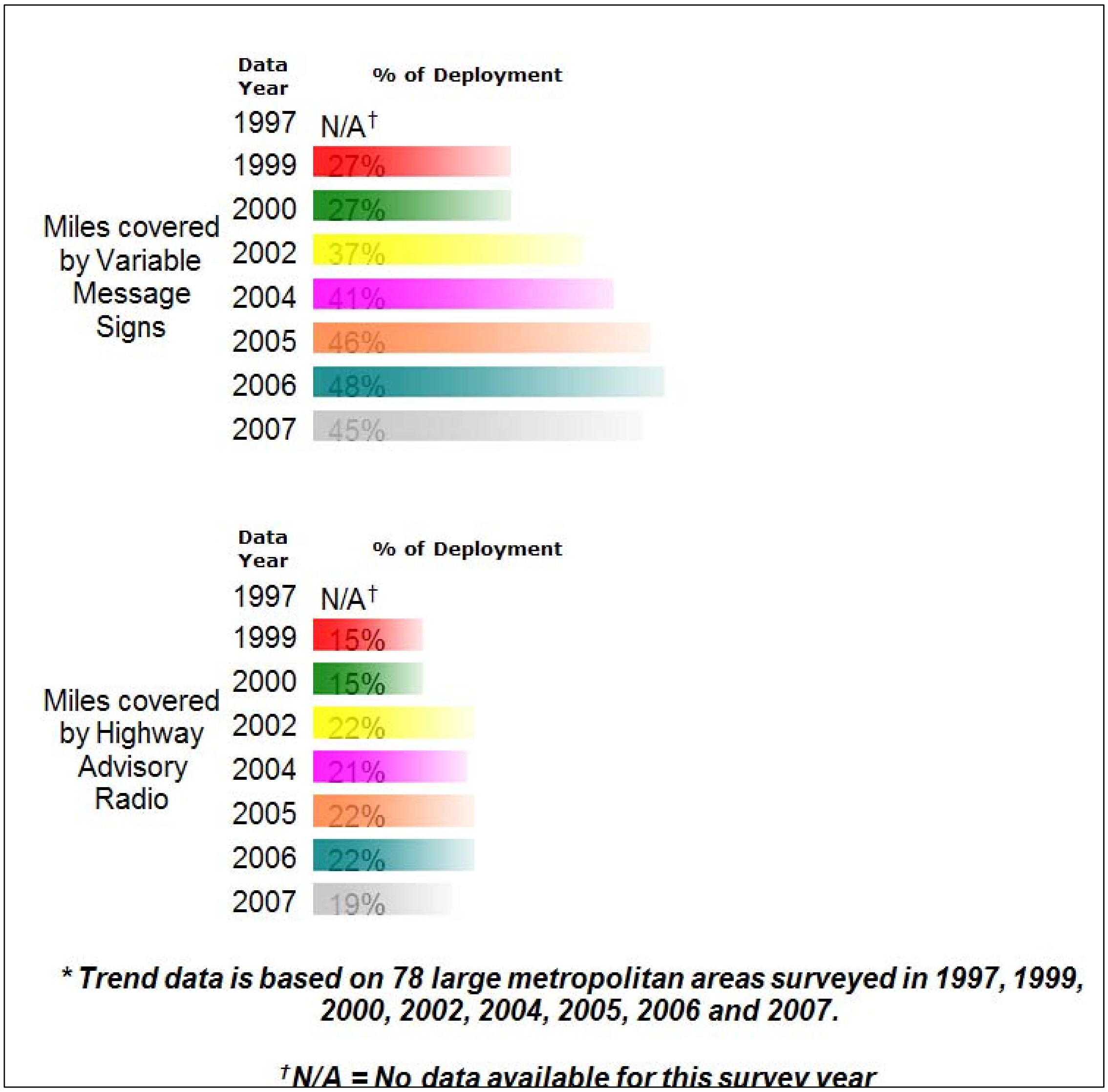
1 Scope

Advanced Traveler Information Systems (ATIS) provide dynamic safety, delay and other information to travelers to help plan their trip (pre-trip) as well as during their trip (on route). The dissemination of traveler information is typically done through internet, cellular phones, telephones, kiosks, television, radio, in-vehicle systems, and fixed road-side ITS (Intelligent Transportation Systems) elements such as changeable message signs, highway advisory radio, etc.

The coverage of highways by fixed ITS elements is limited as shown in Figure 1.

Figure 1. Nationals Trends on ITS Coverage of Freeway Management



Source: Deployment Statistics from Research and Innovative Technology Administration

Traffic delays caused by highway events such as crashes, disabled vehicles, work zones, adverse weather events, and planned special events are called *non-recurring congestion*. About half of all congestion is caused by temporary disruptions that take away part of the roadway from use – or "non-recurring" congestion.

The three main causes of non-recurring congestion are: incidents (25 percent of congestion), work zones (10 percent of congestion), and weather (15 percent of congestion). Travelers and shippers are especially sensitive to the unanticipated disruptions to tightly scheduled personal activities and manufacturing distribution procedures. Aggressive management of non-recurring disruptions, such as incidents, work zones, weather, and special events can reduce the impacts of these disruptions and return the system to "full capacity." (1).

Advanced Traveler Information Systems (ATIS) are a key component in managing the mobility and improving highway safety on the freeways and arterials in California. Studies reveal that travelers appreciate and value timely information on traffic conditions, which reduces the uncertainties in travel times and related stress (2,3). Reliable information on real-time traffic conditions enables travelers to make educated choices about their route, departure time or even transportation mode, with the result of bringing about system self-management towards optimal performance. An evaluation of customer satisfaction with traveler information systems in Seattle found the following benefits of real-time traveler information (4).

- Reduced trip time (43 percent).
- No answer (18 percent).
- More predictable travel (13 percent).
- Less stressful conditions (12 percent).
- Other (8 percent).
- Safer Travel conditions (6 percent).

The travelers benefit more from the availability of real time information about non-recurring congestion sites as they are unforeseen by motorists on route. However, in the absence of any fixed ITS infrastructure or their adaptability to the situation at the impacted location, reliable real-time travel information can not be provided in these situations.

This project is aimed at addressing the ability to more systematically and rapidly deploy **portable** field elements to provide real-time traveler information to motorists in areas where no adequate fixed elements are present and non-recurring delays occur.

1.1 Identification

This concept of operations document is focused on the Portable Advanced Traveler Information Systems (Portable ATIS). This system typically includes a portable traffic detection system, on-site or centralized data processing unit, an information dissemination system such as set of changeable message signs and highway advisory radios and the communication systems needed for these subsystems to work together. Changeable message signs as part of Portable ATIS need to conform to the Caltrans Traffic Operations Policy Directive # 05-07 found at this web link, http://www.dot.ca.gov/hq/traffops/signtech/signdel/policy/05-07.pdf. Portable ATIS may also have Portable CCTV cameras as an optional component.

1.2 Document Overview

This concept of operations document is aimed at better use of Portable ATIS in California by defining the subsystems, their specifications, user requirements and providing an understanding of how the system will operate by demonstrating the use of Portable ATIS in operational scenarios.

The intended audiences of this document are the Caltrans Headquarters Operations and Maintenance personnel, Caltrans District Operations and Maintenance personnel, potential suppliers of Portable ATIS and Caltrans Headquarters IT personnel.

This document describes the current situation in providing traveler information around non-recurring congestion sites at Caltrans Districts 2 and 3, the proposed changes and the justification, as well as the examined concepts for the proposed system addressing the changes. The document is concluded by a presentation of operational scenarios along with a summary of impacts and analysis of the proposed system in terms of limitations and challenges.

1.3 System Overview

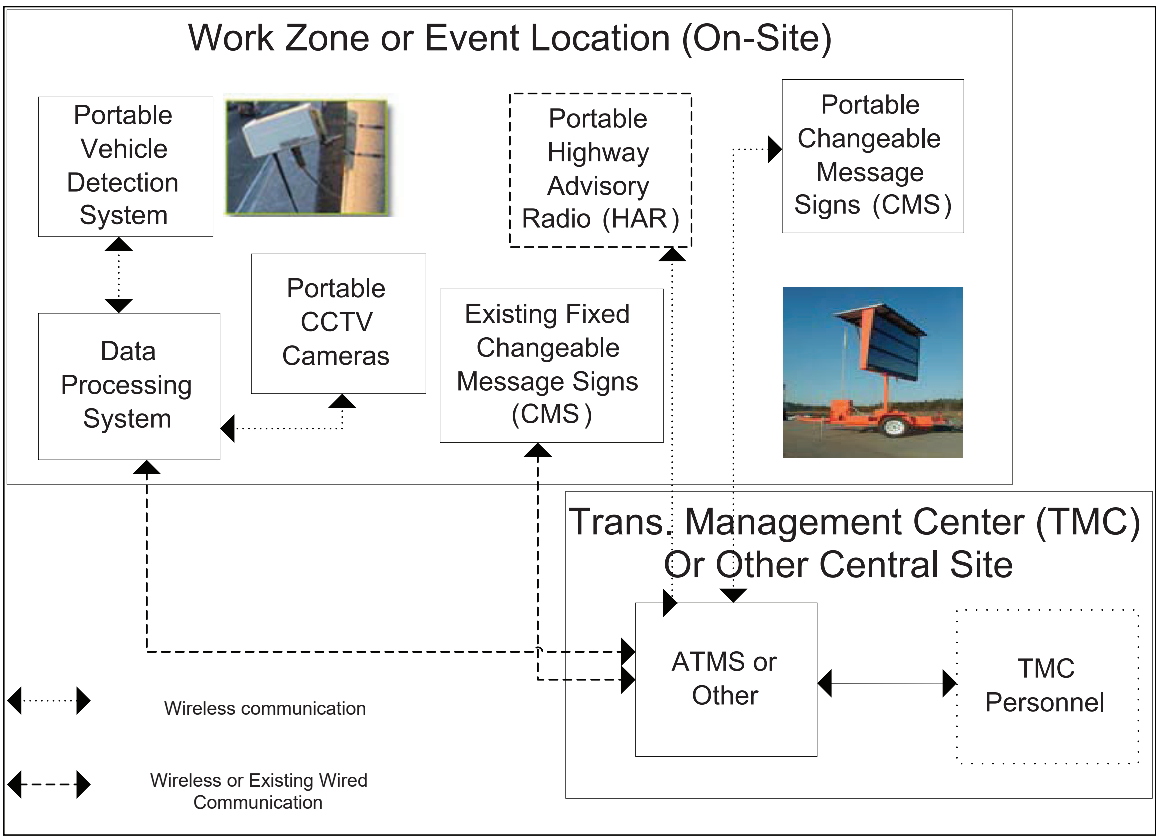
The purpose of Portable ATIS is to provide real-time safety and delay information on non-recurring congestion to the travelers that are on route as well as make this information available to be used for system-wide regional traffic management. Portable ATIS typically includes a portable traffic detection system, on-site or centralized data processing unit, an information dissemination system such as set of changeable message signs or highway advisory radios and the communication systems needed for these subsystems to work together.

The road-side elements as part of Portable ATIS need to meet the crashworthiness requirements as prescribed by Caltrans / Federal Highway Administration. Changeable message signs as part of Portable ATIS need to conform to the Caltrans Traffic Operations Policy Directive # 05-07.

An example depiction of the proposed system is shown in Figure 2. The major components of Portable ATIS are as follows:

1. Portable traffic detection system (e.g., microwave or radar based non-intrusive sensors);
2. Data processing unit (i.e., an on-site or off-site unit to process data from traffic detection system and estimate the travel time or delay for a defined roadway section);
3. Information dissemination system (i.e., Changeable Message signs and Highway Advisory Radios for this effort);
4. Communication systems needed between the above three components (i.e., most of the communication between the components need to be wireless).

Figure 2. Overview of Proposed System (Portable ATIS)



This system ideally will not take more than five hours of set-up and calibration time in the field. The set-up and calibration time includes the time from the arrival of equipment on-site to the time when the first message is online on the CMS or HAR. The system may require further calibrations for another 24 hours. Portable ATIS may be considered for use at the site of a non-recurring congestion event lasting a minimum of one-week duration because of the total time needed in terms of notification, set-up and calibration. This will provide travelers useful real-time safety and delay information.

The traffic detection system, the data processing unit and the communication link between these components and a specified central location (e.g., Transportation Management Center) are critical components of this system. Portable Changeable Message Signs (CMS) are also needed to disseminate the real-time information to the travelers' on route in the absence of fixed CMSs. The messages can additionally be provided through available fixed CMSs in the vicinity. The information dissemination through Highway Advisory Radio is optional and may not be needed at certain instances.

Short descriptions of different components of Portable ATIS are as follows:

- Changeable Message Signs (CMS)
  - Fixed site CMS – Typically located along major highways to deliver general highway/traveler information to travelers
  - Portable CMS – Typically deployed near work zones to inform travelers of delays and to advise them to tune into a HAR frequency for more detailed information
- Data Processing System
  - System which receives the traffic data from the vehicle detection system and calculates estimated delays and related alarms and has the capability to generate messages to display on the CMS
  - To provide TMC staff with estimated delays and related alarms
- Portable Vehicle Detection System:
  - Mobile systems that detect and monitor traffic and assess traffic conditions in real-time in a work zone area or incident location
  - Portable systems that can be easily moved to new locations and recalibrated to accommodate construction staging and traffic flow adjustments/changes
- Highway Advisory Radios (HAR)
  - HARs are available in both AM and FM frequencies
  - Fixed site HAR – Typically located along major highways to deliver detailed highway/traveler information to travelers
  - Portable HAR – Typically deployed near work zones to inform travelers of delays, closures, alternate routes, etc.
- Communication links from a TMC to Portable ATIS site
  - To control CMSs or HARs
  - To observe traffic via a Closed Circuit Television (CCTV) camera if available

   - To receive data from a work zone or incident location (e.g. photo of a highway disruption)
   - To communicate with on-site personnel, Caltrans or contractor
- Communication between an on-site supervisor and a portable HAR and/or CMS
   - Local Area Network (LAN)
   - Cellular or Geostationary (GEO) satellite connection to a portable HAR and/or CMS
- Future traveler information technology - Dedicated Short Range Communications (DSRC) system to provide data communications between a roadside site and a laptop computer or Personal Digital Assistant (PDA) in a vehicle.

The project team has interviewed the potential users of the proposed system and has gathered the user needs into a separate user requirements document. These user requirements are also presented here in this document under the justification for changes section (Section 4.1).

2 Referenced Documents

- Caltrans District 7 has completed a Concept of Operations document for Work Zone Traffic Management System (WZTMS), Version 1.1, September 30, 2008. This system is focused on the use of portable ITS elements in the event of loss of fixed ITS elements due to construction related roadway events. This document is available from Caltrans District 7.

- Final Rule on Work Zone Mobility and Safety, Federal Register / Vol. 69, No. 174, September 9, 2004. This final rule lays out guidance on work zone planning.

- Final Rule on Temporary Traffic Control Devices, Federal Register / Vol. 72, No. 233, December 5, 2007. This rule includes conditions for the appropriate use of, and expenditure of funds for, installation and maintenance of temporary traffic control devices during construction, utility, and maintenance operations.

- Work Zone Operations Best Practices Guidebook, Publication No. FWHA-OP-00-010 April 2000.

- The California Policy: Deputy Directive 60, Dated March 25, 2002.

- Caltrans Transportation Management Plan (TMP) Guidelines dated may 2004.

- Evaluation of Portable Automated Data Collection Technologies: Interim Report, Work Accomplished During Fiscal Year 2005-2006 report by San Diego State University. California PATH Working Paper (UCB-ITS-PWP-2006-9)

Other documents that are referenced in the text of this document are provided in the last section as References.

3 The Current Situation

This section describes the relevant current practices of traffic management around planned and un-planned events on highways using examples from Caltrans Districts 2, and 3.

3.1 Background, Objectives and Scope

The planned and un-planned events on the highways can generally be divided into long-term, mid-term and short-term events. For the purpose of this effort, short-term events are defined as events that last less than a week-long. The mid-term events are defined as events of duration between one-week and one-month long. Events that last longer than one-month are referred to as long-term events.

For long-term planned events, District Traffic Manager reviews the expected traffic conditions as part of developing the Transportation Management Plan (TMP) and recommends use of Portable CMSs, HARs and other systems. Transportation Management Plan (TMP) is required to be developed for all lane closures by the District Maintenance, Operations or other permitted work. For a number of long-term planned events, Caltrans has included a requirement for the construction contractor to provide portable Changeable Message Signs (CMS). The contractor provided CMSs are typically used to provide safety messages (e.g., stopped traffic). Currently, these systems do not typically provide any real-time delay or travel time messages to the traveling public. Most of these systems are not connected to the Transportation Management Center (TMC).

At the short-term and mid-term planned event locations, Caltrans uses arrow boards and other equipment as advised in the traffic management plan (TMP) prepared in accordance with MUTCD and Caltrans policies (e.g., travel delays caused by the event not to exceed 15 minutes).

Most of the unplanned event locations (e.g., road blockage due to mudslide, etc.), does not provide any dynamic safety or delay related information. As indicated in Chapter 1, travelers on route are typically caught unaware of these incidents and do not have all of the information at the right time to make their route selections. Portable ATIS that interacts with a TMC or other centralized location will enable system-wide regional traffic management.

<u>Goal</u>: Provide real-time safety and delay messages related to mid-term and long-term, planned and unplanned events to system-wide traveling public, as needed.

<u>Objectives</u>: The objectives of Portable ATIS are as follows:

- Enable the districts to provide real-time safety and delay related information to travelers on route in time to make appropriate route selections around planned and unplanned events. These events are typically mid-term or long-term.

- Facilitate system-wide regional traffic management by integrating Portable ATIS with existing regional traffic management systems.

Portable ATIS is aimed at overcoming the following challenges with temporary work zone ITS systems currently available in the market place:

1. Available systems providing real-time information at work zones need set-up and calibration times longer than a week;
2. Recent evaluations of portable work zone information systems in California have determined the evaluated systems to be unreliable (i.e., high downtimes) and inaccurate (i.e., errors in delay estimations);
3. Available systems are not readily compatible with ATMS and other software used in the regional Transportation Management Centers (TMC);
4. There are no defined processes for the data from portable ITS elements to be integrated into regional traveler information systems;

Portable ATIS will have a set-up and calibration time of less than five hours, will use a non-intrusive vehicle detection system that does not involve any impact on the roadside, will be connected to the regional TMC or another central location in an automated way needing minimal TMC – staff time.

Modes of Operation: In the current situation, there is no real-time traveler information provided at the locations of most of the unplanned events. At some of the mid-term and long-term planned events on roadways, the end-executors of the activity on the roadway (e.g., construction contractor) are required to provide estimated delay and safety information (i.e., not estimated in real time). The contractors assume the full responsibility for the operations and maintenance of the systems that provide dynamic traveler information at these locations.

Fixed ITS field elements such as CMS and HAR in the vicinity are used sometimes to provide safety and other information near planned and unplanned events on the roadways.

Classes of Users:

1. Traveling Public – these are the travelers on route that need to be informed about the roadway event and related messages in time for them to make route-choice decisions. Portable ATIS will interact with the traveling public through the portable or fixed changeable message signs, HARs and regional Traffic Management Centers (TMC) that can disseminate delay information through other regional traveler information interfaces such as 511 and websites.
2. Set-up and Maintenance Personnel – District personnel, typically maintenance personnel that will be responsible for the on-site equipment and the set up. These personnel are expected to be trained in handling roadside equipment and temporary equipment installation. They will also be responsible for taking the

equipment down and back to the district offices. These personnel make sure that the system is powered on, perform the setting up on-site and house the system during non-use.

3. Operating Personnel – District personnel, typically Transportation Management Center personnel will be responsible for the calibration and actual operations of Portable ATIS. These personnel are trained professionals in telecommunication needs for fixed or portable field elements.

4. Regional Traveler Information Providers: District and Headquarters personnel that are responsible for 511 and other regional traveler information services (e.g., www.511.org). These personnel are very familiar with the TMC systems (e.g., ATMS). These users will interact with Portable ATIS through a TMC system.

Interfaces to Operational Environment: The operational environment of the current situation includes the roadside of the identified event location and TMC procedures for traffic management.

Scope of Current Situation: Current situation as related to the proposed system includes mid-term and long-term events if determined to be needed by the corresponding District personnel. District maintenance personnel house the current equipment used or the construction contractor is required to provide the current equipment as well as operate and maintain it for the life of the project. When the portable CMSs from the maintenance yards are used, the Resident Engineer (if construction zone), District Operations office and TMC personnel coordinate with maintenance on the placement as well as messages on the signs. In the current situation, dynamic traveler information is not typically provided even when Portable CMSs are used.

3.2 Operational Policies and Constraints

For planned events such as construction activities, Caltrans uses three categories of transportation management plans (TMPs) based on the expected work zone impacts of projects.

The first category is a "Blanket TMP." This applies to projects where work is done on low volume roads during off peak hours and no delays are expected. It also applies for moving lane closures. Typical TMP strategies for such projects include portable Changeable Message Signs (CMS), freeway service patrols (FSP), travel management techniques (TMT), and work during off-peak hours.

The second category is a "Minor TMP." The majority of Caltrans road projects fall under this category. Generally such projects cause minimal impacts. Lane closure charts and some mitigation measures are required. Typical TMP strategies for such projects include, night work, portable and fixed CMS, construction zone enhanced enforcement program (COZEEP), TMT, highway advisory radio (HAR), FSP, gawk screens, etc.

The third category is a "Major TMP." About 5% of Caltrans road projects fall under this category. Generally such projects cause significant work zone impacts, and may require multiple TMP strategies and multiple contracts. Typical TMP strategies for such projects include, public awareness campaigns, fixed CMS, extended closures, moveable barriers, COZEEP, detours, reduced lane widths, web site, helicopter traffic reports, etc (5).

Caltrans also provides policy guidance on determining significant traffic impact. As per the guidance, "significant traffic impact is 30 minutes above normal recurring traffic delay on the existing facility or the delay threshold set by the District Traffic Manager (DTM), whichever is less."(6).

Institutional Constraints: Most of Caltrans Districts have two different offices for Operations and Maintenance. This has hindered the use of portable CMSs owned by the districts for the following reasons:

1. Portable CMSs are housed by the maintenance personnel while the operations personnel manage the Transportation Management Centers (TMC);
2. Maintenance personnel are tasked with managing the actual planned and unplanned events on roadways while the operations personnel are responsible for the system-wide traffic management.
3. Because of the divided responsibilities, Caltrans Districts that have two different offices for Operations and Maintenance do not have portable CMSs that are integrated to a TMC.

3.3 Description of the Current Situation

Caltrans District 3 has two different offices for Operations and Maintenance. So, the current situation with providing traveler information around planned and unplanned events on roadways are described here.

Long-term Planned Events (e.g. Work Zones): If the planned events are construction projects, requirements to provide delay information through portable CMSs are included in the construction RFP for some of these projects as needed and the construction contractor typically provides the Portable CMSs and the complete stand-alone system. Typically in those cases the signs are controlled by the contractor and Caltrans requests messages on these signs as necessary either locally or remotely. The District is responsible for the messages on these signs and they monitor them.

If it is a non-construction related work zone and it is determined that a Portable CMS is needed for traveler information, Traffic Management Team (TMT) from Maintenance pulls the Portable CMS trailer to the location and sets it up. These portable CMSs typically have a cellular modem and are controlled using proprietary software at the location. These Portable CMSs are also typically not connected to the Regional TMC.

Mid-Term and Short-Term Planned Events (e.g. Work Zones): District determines whether traveler information using Portable CMSs need to be provided based on the Average Daily Traffic (ADT), the safety risks associated with the work zone, etc. If it is determined that Portable CMSs are needed, then TMT is asked to pull the Portable CMS trailer to the location and set it up. These Portable CMSs are also typically not connected to the Regional TMC.

Incidents / Special Events: District does not typically use portable CMSs at these locations. Static signs as well as any fixed ITS elements near these events are used for traveler information.

In Caltrans District 2, both the Operations and Maintenance are under the same office. The current situation with providing traveler information around planned and unplanned events are described below

Long-term Planned Events (e.g. Work Zones): On a three years-long bridge deck replacement project on a section of Interstate 5 that carried relatively lower Average Daily Traffic (ADT), huge backups (i.e., up to 20 miles of queuing at times) and delay were experienced during major holidays (e.g. Memorial Day). So, District 2 had the Contractor place Multiple Portable CMSs at this work zone before and on major holidays. The Contractor manually controlled these Portable CMSs with messages from the regional Transportation Management Center (TMC).

The Traffic Management Team (TMT) went out and drove tag-runs (i.e., following random cars in the traffic stream and estimating delays at various times of the day) to estimate the delay times and manually radioed those times into the regional Transportation Management Center. The regional Transportation Management Center personal manually controlled the messages on the permanent CMSs and HARs by appropriately placing safety-related messages as well as the delay estimations from the tag-runs by TMT. The contractor did the same update to the portable CMSs via manual control. As part of the contract, the Contractor provided additional Portable CMSs that stayed about 1000 feet ahead of the stopped traffic as the backups grew longer. Permanent CMSs in the neighborhood of this segment of Interstate 5 as well as Highway Advisory Radios were also used to inform the drivers of the estimated delays as well as stopped traffic related safety messages.

Mid-Term and Short-Term Planned Events (e.g. Work Zones): District typically does not provide any real-time delay or safety information around mid – term and short – term events.

Incidents / Special Events: District does not typically use portable CMSs at these locations. Static signs as well as any fixed ITS elements near these events are used for traveler information.

3.4 Modes of Operation for the Current Situation

In the current situation, there is no real-time traveler information provided at the locations of most of the unplanned events. At some of the mid-term and long-term planned events on roadways, the end-executors of the activity on the roadway (e.g., construction contractor) are required to provide estimated delay and safety information. The contractors assume the full responsibility for the operations and maintenance of the systems that provides dynamic traveler information at these locations.

Fixed ITS field elements such as CMS and HAR in the vicinity are used sometimes to provide safety and other information near planned and unplanned events on the roadways. In rural districts, the likelihood of a fixed ITS element near a planned or unplanned event is very low. In Urban areas, availability of fixed ITS elements in the vicinity of an event is more likely. But, the functioning of these fixed elements may themselves be disrupted due to the roadway event. A related research on this topic of utilizing temporary ITS field elements when the fixed ITS elements are affected is currently underway at Caltrans District 7.

3.5 User Classes and Other Involved Personnel

This section describes the organizational structure at the District level showing the personnel that are involved in providing traveler information on planned and unplanned events on California highways and is followed by a short profile on the user classes and the interactions among the user classes.

3.5.1 Organizational Structure

For construction projects on the highways, a Resident Engineer (RE) is assigned as the point person who is responsible for the execution of the construction project. Caltrans Headquarters Operations and Maintenance personnel may provide support and approval of Traffic Management Plans (TMP). As described earlier, some of the Caltrans districts have two different offices for operations and maintenance. Maintenance personnel are typically responsible for any needed activities on site and house the portable CMSs. Operations personnel coordinate with the Resident Engineer and Maintenance personnel as needed on traffic management around construction events. Figure 3 provides a simple depiction of agency stakeholders and typical communication flows for the use of Portable ATIS for planned events.

For planned special events as well as the unplanned events (e.g., incidents), the agency stakeholders and the communication flows are very similar except the absence of Resident Engineer and TMP coordinator at the district. Figure 4 shows a simple depiction of agency stakeholders and typical communication flows for the use of Portable ATIS for unplanned events.

The regional Traveler Information entity could be the 511 system as well as any other advanced traveler system that is used in the region by the traveling public.

Figure 3. Agency Stakeholders and Organization for Planned Events

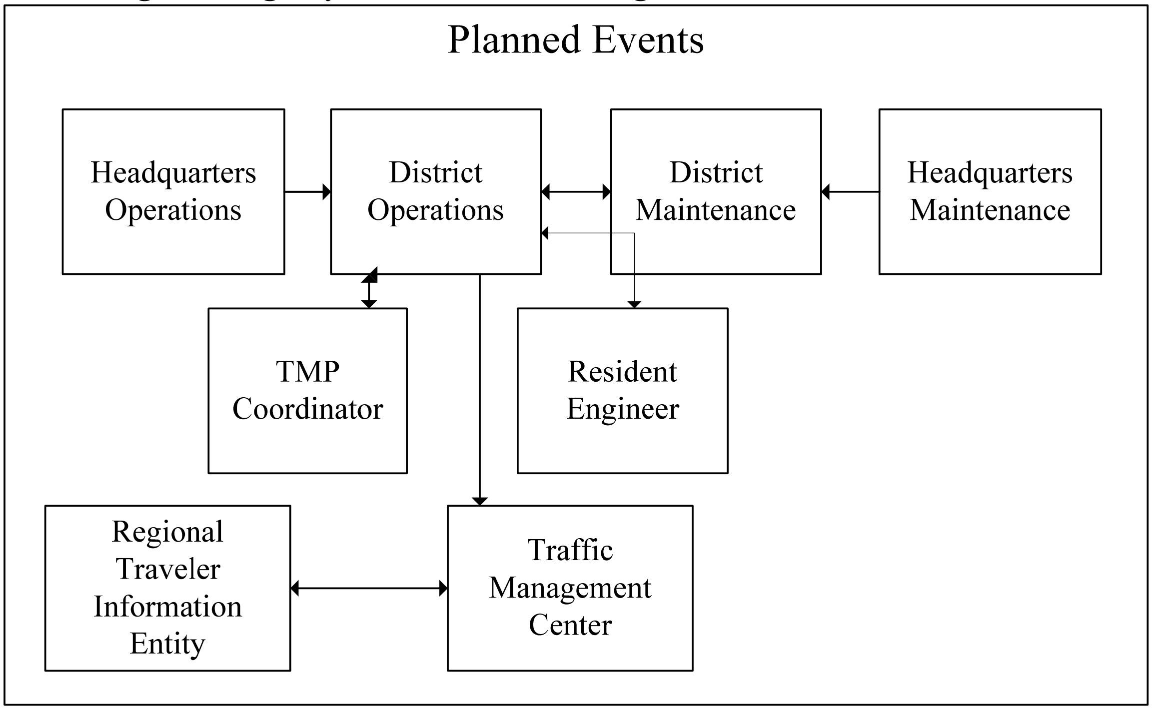
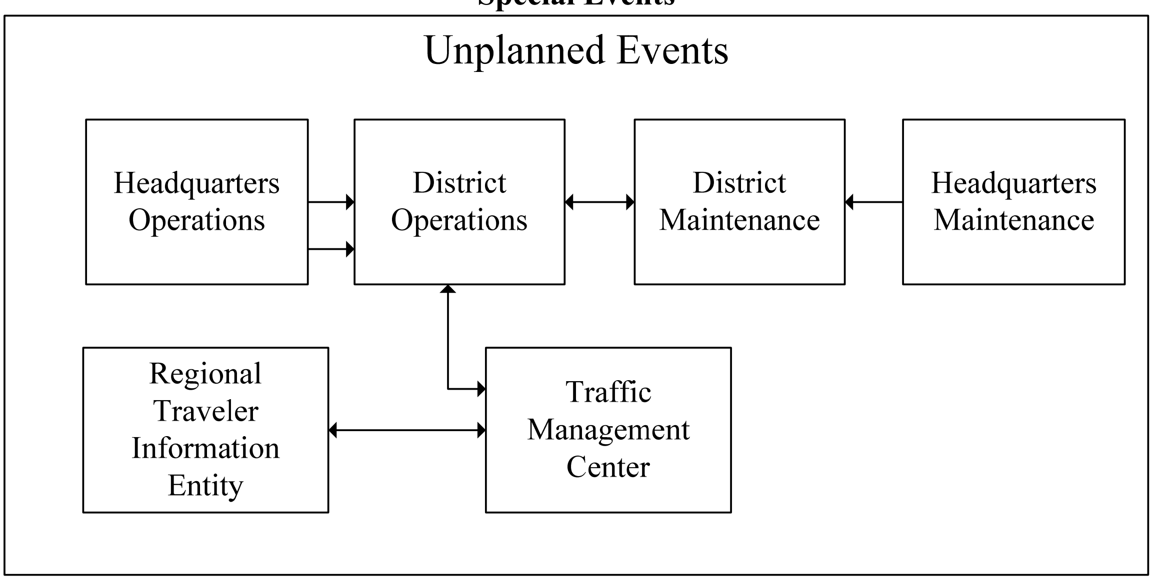


Figure 4. Agency Stakeholders and Organization for Unplanned and Planned Special Events



3.5.2 Profiles of User Classes

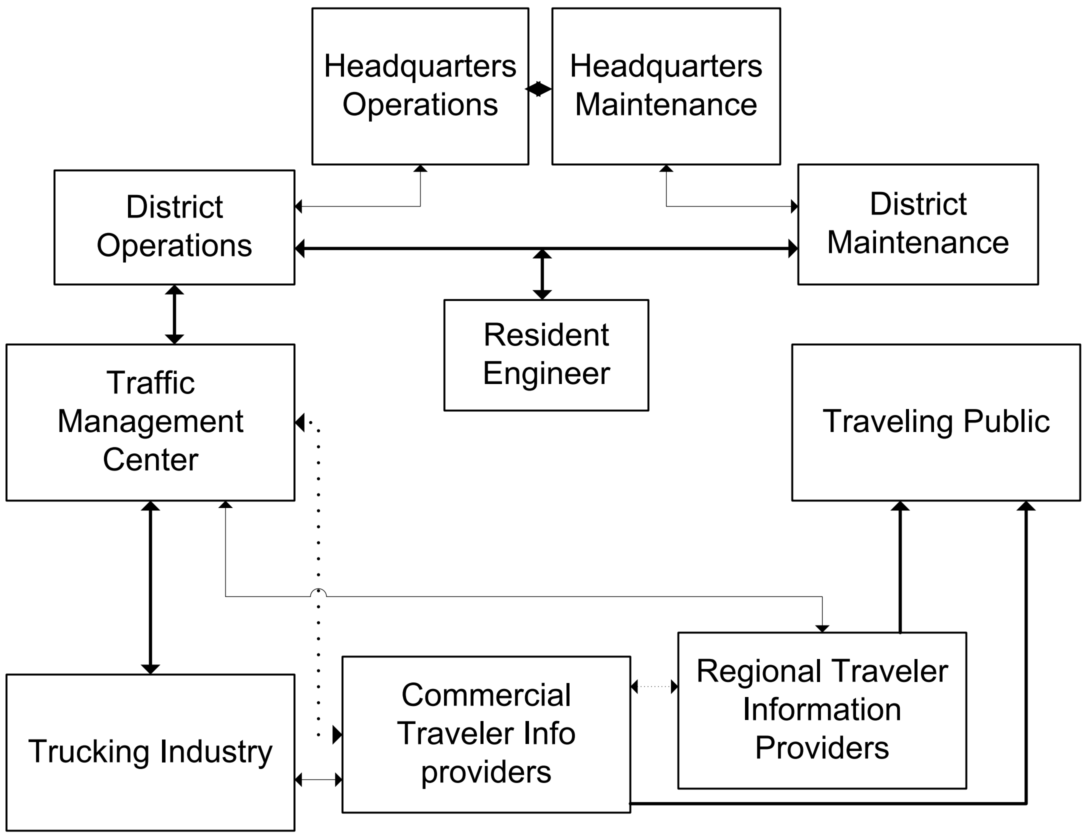
The users of current system (i.e., stand-alone contractor supplied dynamic information systems at work zones) can generally be categorized as the stakeholders within the agency (i.e., Caltrans) and non-agency stakeholders. Non agency stakeholders can be local transportation authorities (e.g., city or county transportation personnel, local EMS personnel, traveling public, local trucking entities). Until Portable ATIS is mainstreamed in California, the potential providers of Portable ATIS are stakeholders as well. The following list of user classes includes agency and non-agency stakeholders.

1. Resident Engineers (RE): Resident Engineer (RE) is the Project Manager at the construction site / project level. Makes TMP changes based upon events. The Resident Engineer keeps the District Transportation Management Center well informed and up to date on the construction progress, delays, closures, and other information which may assist them in the performance of their duties. The Resident Engineer coordinates the use of Changeable Message Signs through the District Transportation Management Center. The Resident Engineer provides guidance to CHP officers performing COZEEP (Construction Zone Enhanced Enforcement Program) support.
2. Traveling Public – these are the travelers on route that need to be informed about the roadway events and related messages in time for them to make route-choice decisions. Current systems when used, inform the traveling public through the portable or fixed changeable message signs, and other regional traveler information interfaces such as 511 and websites.
3. Set-up and Maintenance Personnel – District personnel, typically maintenance personnel are responsible for the on-site equipment and set-up. These personnel are expected to be trained in handling roadside equipment and temporary equipment installation. They are also responsible for taking the Caltrans equipment down and back to their district offices.
4. Operating Personnel – District personnel, typically Transportation Management Center personnel are responsible for the field ITS elements, calibration and actual operations. In the current situation, Construction contractors are required to provide portable CMS and portable traffic detection systems. These contractors are also typically responsible for the set-up, calibration and operations of the equipments they provide. District personnel typically have access to the contractor-provided equipment through the contractor. These personnel are trained professionals in telecommunication needs for fixed or portable ITS field elements.
5. Regional Traveler Information Providers: District and Headquarters personnel that are responsible for 511 and other regional traveler information services (e.g., www.511.org). These personnel are very familiar with the TMC systems (e.g., ATMS). These users typically interact with a TMC system.

3.5.3 Interactions between User Classes

As described earlier, a greater cooperation among the operations and maintenance personnel at the district level is needed. Figure 5 presents a simplistic representation of the interaction among the user classes of the current situation (i.e., stand-alone dynamic information systems at construction zones or other planned events).

Figure 5. Interaction among User Groups



Traveling public interacts with all of the other groups through the field element (i.e., portable CMS) or through Regional or commercial traveler information providers.

3.5.4 Other Involved Personnel

As noted above, the Caltrans Division of Operations and Division of Maintenance at the Headquarters influence the policies and procedures for the use of ITS and other systems at the planned and unplanned events. Other involved personnel (i.e., stakeholders) are grouped into the following two categories.

1. Other Agency Stakeholders: Headquarters operations and maintenance personnel provide needed direction and assistance to the Districts' operations and maintenance personnel respectively. Headquarters Division of Operations and

Division of Maintenance help set policies and procedures related to technology deployments.

2. Other Non-Agency Stakeholders: Commercial traveler information providers may also be utilizing the information that is provided by the Transportation Management Center on current roadway events.

   Trucking industry representatives are also affected by the planned and unplanned events on the roadways. The trucking industry may interface with the current systems like the traveling public through the CMS, HAR and additionally through communication from a TMC to their dispatch centers.

3.6 Support Environment

Caltrans Districts require bidders for the construction projects to provide Portable CMSs for certain projects where they expect safety issues or largely varying long delays. Construction contractors usually have a subcontractor that is responsible for setting up and operating these portable CMSs. These subcontractors are responsible for the full operations of the system that is typically stand alone and has no or limited connectivity to any Caltrans systems.

Transportation Management Center (TMC) operators use Advanced Transportation Management Software (ATMS) to detect and mange traffic backup from incidents, expedite incident clearance, and manage disasters and special event traffic situations. The ATMS data also feeds the Department's Performance Measurement System (PeMS) used by others within the Department and externally, including researchers and ISPs.

Commercial traveler information service providers obtain current and archived information from freeway Performance Measurement System (PeMS).

Some districts with ATMS software are able to provide feeds of messages they post on Changeable Message Signs (CMS) that are typically fixed and owned by Caltrans. Typically these messages are incident or other delay related, warning drivers to take specific defensive actions such as accident ahead / merge left / lane closed.

4 Justification for and Nature of Changes

The current offerings of systems that are closest in definition to Portable ATIS are typically called smart work zone systems, work zone intelligent transportation systems, etc. These systems as described in Chapter 3 are typically stand-alone systems that collect traffic information, process the information, and display messages based on the processed information on the Portable CMS signs that come with the system. Some of these systems do offer HAR and Road Weather information Systems (RWIS) as part of the system. Rarely are these systems connected to a Transportation Management Center (TMC). When these systems are connected to a TMC, they have a manual interface in most of the cases.

The current set of portable ATIS available commercially has discouraged the use of Portable ATIS to manage traffic around mid-term planned and unplanned events on roadways. Portable ATIS as defined in this effort (i.e., linked to a central location and short set-up time) will enable their use at mid-term and long-term, planned and unplanned events on roadways.

As indicated in Chapter 1, the non-recurring congestion due to planned and unplanned events on roadways is about half of all congestion on roadways. An effective way of mitigating non-recurring congestion is to get real-time dynamic information on the non-recurring congestion to the travelers on-time either pre-trip or on route so that the travelers can find an alternate route or adjust their start time and expected arrival times at their destination. This calls for the use of Portable ATIS to inform travelers on route as well as travelers planning a trip through the location of the non-recurring congestion. Portable ATIS is needed when there are no existing fixed ITS elements near the event location or the existing fixed ITS elements may be affected due to the planned or unplanned event. For example, fixed CMSs and HARs near a construction zone may be out of commission because of the disruption to the fiber communication that links the specific CMS to the TMC.

4.1 Justification for Changes and User Requirements

The following list of user needs for Portable ATIS has been gathered by interactions with Caltrans District and Headquarters Operations and Maintenance personnel to reflect Caltrans practice in managing work zones and other planned and unplanned events on highways. Portable ATIS may have one or more Portable Changeable Message Sign (PCMS) and one or more Portable Vehicle Detection System (e.g., Microwave Vehicle Detection System).

The user needs are divided into functional areas for the ease of correlation. The Portable ATIS needs to accommodate most of the following:

4.1.1 Traveler Information and Display Requirements

The overall purpose of the Portable ATIS is to inform the traveling public of the delay, or travel time to pass through or information on alternative routes to a defined multilane or freeway roadway segment consisting of an incident, work zone or other planned event. The Portable ATIS should accurately measure traffic conditions and calculate the delay, travel time or an equivalent surrogate measure. It is desired that this system also has the capability to detect queues and generate related warning messages. Requirements governing displayed information include the following:

1. The on-site processing unit or the central processing unit of the Portable ATIS shall have the option to calculate one of the following:
    a. Total travel time through the work zone / incident area or a defined segment of roadway and presence of stopped traffic along with an estimate of queue length from the Portable ATIS location;
    b. Total delay time through the work zone / incident area or a defined segment of roadway and presence of stopped traffic along with an estimate of queue length from the Portable ATIS location; or
    c. An equivalent surrogate measure to delay or travel time through the work zone / incident area or a defined segment of roadway and presence of stopped traffic along with an estimate of queue length from the Portable ATIS location.
2. The estimated delay time or travel time that is estimated by the Data Processing System to be automatically displayed on Portable CMSs shall have an accuracy range of ± 5 minutes with respect to the actual delay time or travel time through the work zone, incident, or defined segment of roadway.
3. Portable ATIS shall identify all instances of stopped or slow traffic and the estimated queue length of stopped or slow traffic from the Portable ATIS location shall have an accuracy range of ± $1/8^{th}$ of one mile.
4. Automatically displayed messages must be able to be defined by the system user at a remote central location or at a TMC responsible for the highway location. The system shall also have a message library with standard messages approved by Caltrans.
5. The system shall enable the system user to override existing messages with other messages of higher priority at a remote central location or a TMC (e.g. safety warnings over delay information).
6. The system shall have the capability for TMC personnel to turn on and turn off the automated messaging. However, real time traffic conditions (speeds/volumes/calculated delay and travel time) and associated alarms shall continue to be fed into a TMC.

7. The displayed / broadcast messages should be automatically updated every two minutes.
8. Any time measurements displayed shall be rounded up to the nearest whole number of minutes if stopped delay is displayed and to the nearest 5-minutes interval if total delay time or total travel time is displayed.
9. The system shall automatically log all system or component failures, the duration of the failures as well as all of the traffic conditions and messages generated by the Data Processing System and override messages by a TMC with accurate time stamps. This logged data will be maintained in a database that can be accessed and downloaded remotely at regular intervals.

4.1.2 Placement Requirements

The Portable Changeable Message Signs (CMS) component of the Portable ATIS shall display the traveler information to all directions of travel lanes affected by the work zone or incident. The following general requirements govern the placement of field elements involved in making this system function.

1. The location of Portable CMSs will vary based on the design of the work zone and the incident area. Signs may be located at the first vehicle of the queue or may need to be dynamically located at the half or two-thirds length of the estimated longest queue length for a 15-minute closure for the given highway location.
2. The system should be such that the display and other system components could be placed where there are paved or unpaved shoulders available at the location in conformance with Caltrans policies and guidelines on Portable CMS placements.
3. The system should be non-intrusive (e.g. exclude in-pavement sensors, other components that require extensive on-road installations).

4.1.3 Communication Requirements

Caltrans rural districts (e.g., District 1 and 2) and other districts have highways that pass through terrain where there are numerous communication challenges. Therefore, the communication system for the Portable ATIS shall meet the following requirements.

1. The system shall be able to communicate in work zones or incident areas with no line of sight between possible locations of the different system components.
2. The system shall be capable of successful deployment in areas with no or poor cell phone coverage.
3. The system should preferably use a type of communication that has the least amount of recurring costs per use.

4. The system shall be able to overcome any communication interference from roadsides or other vehicles passing through the work zone or incident areas.
5. The on-site processing unit shall be able to be accessed by the regional Traffic Management Center through a secure method acceptable to Caltrans.

4.1.4 Input Requirements

The system shall require a minimal amount of human input and shall have the capability to be customized to the specific location. The following requirements are based on this vision.

1. The system shall account for possible manual errors whenever there is a manual input required, using appropriate error-checking and quality control mechanisms.
2. Use of manual inputs shall be minimized and avoided if possible.
3. The system shall log all the displayed messages with a time stamp.
4. All of the communications shall be secure and acceptable by Caltrans standards.

4.1.5 Ease-of-Use Requirements

The incidents where Portable ATIS are used may last multiple days. But, a typical work zone is expected to be set-up within two hours. Therefore, it is expected that the set-up requirements of the Portable ATIS should not add too much additional effort.

1. The system shall require no more than five hours to be set-up, activated and calibrated at the location.
2. The system shall not require commercial power sources.
3. The system shall not require more than nominal repair and regular maintenance.
4. The system shall be portable comparable to other work zone / incident area traffic control elements (e.g. cones, temporary traffic controls, standard PCMS, etc.).

Based on the user requirements gathered above, the current offering of smart work zone systems has the following shortcomings:

a. Set-up and calibration time of multiple days (i.e., from three days to about a week);
b. Communication requires cell phone coverage;
c. No standard interface with the ATMS systems at a TMC;
d. Past evaluations of the systems indicate a high level of downtimes and errors in delay estimations;

There are also the institutional challenges discussed in Section 3.2 that discourages the use of the current smart work zone systems offered in the market place at mid-term planned and unplanned events.

4.2 Description of Desired Changes

The user requirements above allow either for a single system consisting of CMSs, HARs, Portable Vehicle Detection Systems, Data Processing system along with the communication links that connects to the regional TMC or a set of sub-systems that are located in the vicinity (i.e. Existing Portable CMSs at the districts displaying messages generated by the Portable Vehicle Detection Systems and Data Processing System, or Portable Vehicle Detection Systems and Data Processing Systems used by the regional TMC when fixed CMS and HARs are located in the vicinity).

The following are a list of desired changes:

4.2.1 Capability Changes

This section describes the functions and features to be added, deleted, and modified in order for the Portable ATIS to meet its objectives and requirements.

One of the major changes desired is that the Portable ATIS be easy to set-up (i.e., the set-up and calibration of less than five hours). This may require having portable sub systems that are field-ready needing minimal amount of set-up.

When Portable ATIS includes one or more CMSs, the messages displayed on these signs should be controllable from a TMC.

4.2.2 System Processing Changes

The following are changes in the process of transforming data that will result in messages displayed on fixed and portable CMSs and HARs.

1. The delays or travel times estimated by Portable ATIS should be accurate to ± 5 minutes with minimal amount of system downtime;

2. Portable ATIS should also have communication options other than cell phone to be linked to the TMC as well as inter-component communication so that it can be deployed in areas where there are no or poor cell coverage;

4.2.3 Interface Changes

Changes in the system that will cause changes in the interfaces and changes in the interfaces that will cause changes in the system are described here. The user requirement that Portable ATIS needs to be connected to the Transportation Management Center is needed to enable the districts to:

a. Utilize any fixed ITS elements nearby to inform travelers of non-recurring congestion ahead.
b. Manage the traffic in a system-wide manner to efficiently accommodate the traffic demands.

This means that Portable ATIS should have standardized interfaces among Portable Vehicle Detection System, Portable CMSs, HARs and the Advanced Traffic Management System at the Transportation Management Centers (TMC). Currently ATMS v2 is run in most of the districts with few exceptions.

4.2.4 Personnel Changes

The following changes are recommended to enable collaboration between personnel from Maintenance and personnel from Operations.

In Caltrans districts that have two different offices for Operations and Maintenance, a collaborative procedure to deploy Portable ATIS needs to be established because all of the portable equipment is housed and maintained by the Maintenance and the Operations need to collaborate with Maintenance to have the equipment transported and set up at the location of interest.

4.2.5 Environment Changes

Posting of the messages generated by Portable ATIS to the CMSs should be **automated with manual override**. The broadcasting of messages through the HAR is also desirable to be automated. This results in a change in the operational environment that causes changes in the system functions, processes, interfaces, or personnel.

4.2.6 Operational Changes

There are no changes to the user's operational policies, procedures, methods, or daily work routines expected in this version of Concept of Operations. As described in Section 4.2.4, a new procedure may be developed for collaborative deployment of Portable ATIS by both maintenance and operations personnel at the district.

4.3 Priorities among Changes

Based on the user needs in Section 4.1, the desired changes are classified into the following three categories.

4.3.1 Essential Features

The following features are essential.

1. Portable ATIS should be easy to set-up (i.e., the set-up and calibration of less than five hours). This may require having portable sub systems that are field-ready needing minimal amount of set-up. If the system set-up and calibration takes longer than a day (i.e., 24-hr period), the system may not get used in mid-term planned and unplanned events that may last just one or two weeks;

2. Posting of the messages generated by Portable ATIS to the portable CMSs should be **automated with manual override**.

3. Portable ATIS should have standardized interfaces among Portable Vehicle Detection System, Portable CMSs, HARs and the Advanced Traffic Management System at the Transportation Management Centers (TMC). Currently ATMS v2 is run in most of the districts with few exceptions. If these interfaces are not standardized, a TMC may not be able to post the automated messages from the Portable ATIS to the fixed CMSs and HARs near the location;

4. In Caltrans districts that have two different offices for Operations and Maintenance, a collaborative procedure to deploy Portable ATIS needs to be established because all of the portable equipment is generally housed and maintained by Maintenance and Operations needs to collaborate with them to have equipment transported and set up at the location of interest;

5. When Portable ATIS includes one or more portable CMSs, the messages displayed on these signs should be controllable from a TMC.

4.3.2 Desirable Features

The following features or capabilities are desired and are listed in decreasing priority. Reasons why these features are desirable are also explained.

1. When Portable ATIS includes one or more portable CMSs, the messages displayed on these signs should be viewable from the TMC. This feature will enable the TMC personnel to verify whether the updated message gets posted and is displayed correctly.

2. The delays or travel times estimated by Portable ATIS should be accurate to ± 5 minutes with minimal amount of system downtime. Caltrans and FHWA desire the delay and travel times posted to be accurate to ± 2 minutes. Since this system is expected to be set-up and calibrated in five hours, the accuracy of Portable ATIS can't be lower than this desired level (i.e., ± 5 minutes).

3. Downtimes deplete the credibility of the system and its' usefulness. So, total downtime of Portable ATIS should be typically less than ten percent of the total deployment time and the duration of any downtime should not exceed more than 24 hours;

4. Portable ATIS should also have communication options other than cell phone to be linked to a TMC as well as inter-component communication so that it can be deployed in areas where there are no or poor cell coverage. This feature is desired

as Portable ATIS will be used in California areas where the terrain results in poor or no cell phone coverage;

5. The broadcasting of messages through fixed CMSs and HARS near the location incident and portable HARs is also desirable to be automated. This feature will encourage the use of Portable ATIS at the mid-term planned and unplanned events since the human resources needed for operations of Portable ATIS will be minimal while allowing the system-wide management of traffic.

4.3.3 Optional Features

The following are features that might be provided by Portable ATIS. Reasons why these features are optional are also explained.

1. Highway Advisory Radio (HAR) is an optional feature in Portable ATIS. If the impact of the roadway event is estimated to be significantly far into the upstream of a particular approach, available fixed HARs or portable HARs may be used to inform the drivers of impending roadway event and related delays. But using HARs is not an essential feature;

2. The location of Portable CMSs will vary based on the design of the work zone and the incident area. Signs may be located at the first vehicle of the queue or may need to be dynamically located at the half or two-thirds length of the estimated longest queue length for a 15-minute closure for the given highway location. This feature of locating the portable CMSs dynamically based on the queue length requires that the portable CMS and HARs be a well-defined and packaged subsystem to be moved and reset in a very short time period. This feature will be helpful but is not essential as multiple CMSs may be placed at strategic locations to inform the traveling public appropriately.

4.4 Changes considered but not included

In the first version of the Concept of Operations document, it is expected that all of the desired changes listed above can be accomplished by Portable ATIS. The following feature for Portable ATIS is considered and is not included in this effort.

The automation of safety messages like the delay / travel time messages was considered and is not included in the current effort. Portable ATIS shall also display safety related messages such as stopped traffic ahead. This is possible only when the portable traffic detection systems can also detect stopped traffic as well as estimate the approximate queue length. Automation of the safety messages and prioritizing delay related messages on portable or fixed CMSs and HARs was considered and was not included in this effort as this will expand the scope of this effort significantly.

4.5 Assumptions and Constraints

The following are the assumptions for the proposed system (Portable ATIS).

- Existing portable CMSs with the district maintenance offices are expected to not be available to be used as part of Portable ATIS;
- The size of the roadway event is expected to be such that portable vehicle detection at not more than two locations for each travel direction (i.e., each direction of traffic, ramp, etc.) is needed;
- The Portable ATIS equipment will be stored at the district offices or provided by an identified on-call contractor and will be transported to the event location within 24-hours of request;
- All of the communication between the components of Portable ATIS will be using secure communication methods acceptable to Caltrans.
- All of the Portable ATIS roadside equipment will meet the current standards set forth by FHWA and Caltrans.
- Removal of Portable ATIS equipment from the event location and transportation to the district facility is assumed to take not more than 24-hours.
- Use of Portable ATIS for roadway events that are less than one week in duration is not recommended based on the assumption that the notification of the event and the process of deciding to use the system at a particular event along with the set-up / calibration / removal time will allow for a very short period of actual deployment for the system and may not be beneficial with few exceptions (e.g., a planned short-term event on a heavily traveled commuter corridor with alternate routes).

The following constraints are for the proposed system (Portable ATIS).

- Costs of available smart work zone systems are prohibitive of districts owning these systems at their maintenance facilities and using them at the needed roadway events. So the life-cycle cost of proposed Portable ATIS should be reasonable so that the districts can own multiple systems;
- In the event that Caltrans decides not to own this equipment, the providers of Portable ATIS are expected to be capable of entering into an on-call agreement with districts to provide Portable ATIS services when requested;

- Portable traffic detection systems should be non-intrusive and should not interfere with the operational processes related to the roadway event. The deployment of portable traffic detection systems should not require more than a two-person crew and should be within the desired set-up and calibration time for the overall system (i.e., Portable ATIS).

The following policies are the practices of interest to Portable ATIS.

- Caltrans has adopted a practice to strive to limit the delay for lane closures on freeways not to exceed 15 minutes;
- The Traffic Management Plan (TMP) for Work Zones should include any use of ITS elements;
- Changeable Message Signs need to conform to the Traffic Operations Policy Directive # 05-07 found at the following web link; http://www.dot.ca.gov/hq/traffops/signtech/signdel/policy/05-07.pdf

5 Concepts for the Proposed System

As noted in the previous chapters, typically no dynamic delay or travel time information around short-term and mid-term planned and unplanned events is provided to the traveling public on route or pre-trip in the current situation. As explained earlier, providing the travelers with real-time information on the non-recurring congestion due to the roadway events is the most effective way to manage the traffic system-wide. The proposed system (Portable ATIS) will have the following major components:

1. Portable traffic detection system (e.g., microwave or radar based non-intrusive sensors);

2. Data processing unit (i.e., an on-site or off-site unit to process data from the traffic detection system and estimate the travel time or delay for a defined roadway section);

3. Information dissemination system (i.e., Changeable Message signs and Highway Advisory Radios for this effort);

4. Communication system needed between the above three components (i.e., most of the communication between the components need to be wireless).

Portable Traffic Detection Systems: The real-time delay or travel time information can be provided with available fixed sensing systems. In this case, it is expected that the Transportation Management Center (TMC) is receiving the data from the fixed traffic detection systems and the Advanced Transportation Management Systems at the TMC already has a program to detect roadway events and delays around them. In this scenario, portable CMSs and HARs may still be needed at the event location depending on the proximity of fixed CMSs and HARs. The change from the current situation is that these portable CMSs and HARs will be providing real-time delay or travel time information and may provide safety information as well. In the current situation as described earlier, portable CMSs are currently used to provide information such as “Work Zone Ahead”, “Slow Down”, etc.

Information Dissemination Systems: The real-time delay or travel time information needs to be provided to the driving public pre-trip as well as on route. Pre-trip information can be provided by a TMC using the systems that are currently used for system wide traveler information (e.g., 511). To achieve this, Portable ATIS should be able to communicate with a TMC (i.e., typically ATMS v2) using standardized interfaces so that the information from Portable ATIS can be automatically disseminated to the system wide traveler information outlets.

On route information to the travelers needs to be provided at strategic locations where the travelers can also take an alternate route when available. For planned events on roadways, the TMP should consider use of Portable ATIS such that the locations of Portable CMSs and HARs allow the drivers to take the available alternate routes, if any. In certain mid-term unplanned events, locating portable CMS and HARs strategically may be possible. The locations of the portable CMSs and HARs may be decided by the maintenance personnel with local knowledge and they will be responsible for setting the system up at the unplanned event location.

Data Processing Unit: This component of Portable ATIS may not be needed when existing fixed traffic detection systems are connected to a TMC and data is being used for delay or travel time estimation by the ATMS at the TMC. When portable traffic detection systems are used, a data processing unit is needed to receive and process the data from the detection systems and to generate delay, travel time and / or safety related messages.

The data processing unit is expected to be typically located at the location of the roadway event along with other field equipment. So, the data processing unit is expected to be field ready and comply with all the standards for roadside equipment. But, this data processing unit may be located at a TMC if the portable traffic detection systems can communicate their data to the TMC near real-time (i.e., latency in communication not disallowing updating of messages every two minutes or less).

Communication Systems: The communication links among all the components on-site has several options. The communication between the on-site equipment of Portable ATIS and a TMC may also vary. A short survey of options is provided below:

- Communication to/from a Transportation Management Center
    - Any existing telecommunication infrastructure;
    - To a roadway event site
        - Where available, an Radio Frequency (RF) link in any frequency band for voice communication or low rate data transmission;
        - Where available, a cellular link for voice communication or low rate data transmission;
        - A Low Earth Orbit (LEO) satellite link for voice communication or low rate data transmission;
        - Where available, an RF link in the 700MHz band for high data rate (384 kb/s) transmission;
        - Where available, a wideband cellular link (e.g., 1xRTT, EV-DO, GPRS or EDGE);

        - Where available, a Geostationary (GEO) satellite link.
    - To a CMS and/or HAR
        - Where available an RF link in any frequency band for voice communication or low rate data transmission;
        - Where available a cellular link for voice communication or low rate data transmission;
        - A LEO satellite link, except, perhaps in irregular terrain that would cause significant delays between transmissions;
        - Where available a GEO satellite link.

- Communication from a roadway event site
    - To a CMS and/or HAR or to a flag site in order of preference
        - An RF repeater relay in whatever frequency band is available/appropriate;
        - Where available a cellular link for voice communication or low rate data transmission.

- Communication to/from a TMC or roadway event site to a high data rate field element (e.g., traffic detection system, Closed-circuit Television (CCTV))
    - An RF repeater relay in a high bandwidth frequency band (e.g., 700 or 900 MHz);
    - Where available a wideband cellular link (e.g., 1xRTT, EV-DO, GPRS or EDGE);
    - Where available a GEO satellite link.

- Communication to/from a TMC or roadway event site to a remote CMS and/or HAR (to give travelers detailed delay or closure information)
    - Where available a cellular link for voice communication or low rate data transmission;
    - A LEO satellite link;
    - Where available a GEO satellite link.

5.1 Background, Objectives and Scope

Most of the unplanned event locations (e.g., road blockage due to mudslide, etc.), does not provide any dynamic safety or delay related information. As indicated in Chapter 1, travelers on-route are typically caught unaware of these incidents and do not have all of the information at the right time to make their route selections. Portable ATIS that interacts with a TMC or other centralized location will enable system-wide regional traffic management. The following goal, objectives are **the same as the current situation** (Chapter 3) because the information related to Portable ATIS is discussed in the current situation.

Goal: Provide real-time safety and delay messages related to mid-term and long-term, planned and unplanned events to system-wide traveling public, as needed.

Objectives: The objectives of Portable ATIS are as follows:

- Enable the districts to provide real-time safety and delay related information to travelers on route in time to make appropriate route selections around planned and unplanned events. These events are typically mid-term or long-term.

- Facilitate system-wide regional traffic management by integrating Portable ATIS with existing regional traffic management systems.

Portable ATIS is aimed at overcoming the following challenges with temporary work zone ITS systems currently available in the market place:

1. Available systems providing real-time information at work zones need set-up and calibration times longer than a week;

2. Recent evaluations of portable work zone information systems in California have determined the evaluated systems to be unreliable (i.e., high downtimes) and inaccurate (i.e., errors in delay estimations);

3. Available systems are not readily compatible with ATMS and other software used in the regional Transportation Management Centers (TMC);

4. There are no defined processes for the data from portable ITS elements to be integrated into regional traveler information systems;

Portable ATIS will have a set-up and calibration of time of less than five hours, will use a non-intrusive vehicle detection system that does not involve any impact on the roadside, will be connected to the regional TMC or another central location in an automated way needing minimal TMC staff time.

Modes of Operation: Proposed Portable ATIS may use existing fixed traffic detection systems instead of a portable vehicle detection system, if available. The communication between the on-site components of Portable ATIS and a TMC or a centralized location may also use existing communication infrastructure such as fiber-optic communication available to the department.

Portable ATIS can be used for events on both rural and urban roadways. The communication needs for rural events are significantly different from urban events. The criteria for determining the need for Portable ATIS to manage a rural event will also be different from an urban event.

Classes of Users:

The user classes for the proposed system include everyone described in the current situation and a few additional user classes (e.g., potential Portable ATIS suppliers) are added for the proposed solution.

Interfaces to Operational Environment: The operational environment of Portable ATIS includes the roadside of the identified event location, TMC procedures for traffic management, the Traffic Management Systems at a TMC and its interface with any regional traveler information services. Portable ATIS will be able to interact with TMC systems with minimal set-up and calibration requirements (i.e., five hours or less).

Scope of Portable ATIS: Portable ATIS will be typically used at mid-term and long-term event locations if the corresponding District personnel determine the need. District maintenance personnel will house the Portable ATIS system and should work with the District operations and TMC personnel for successful deployment.

5.2 Operational Policies and Constraints

All of the policy constraints described in Section 3.2 applies to the proposed system as well. Additionally, the following are policies that are of concern to Portable ATIS.

1. Crashworthy Temporary Traffic Control Devices in Work Zones Categories 1, 2 and 3 as part of Caltrans MUTCD (7);
2. Use of safety-related message on changeable message signs (8);
3. Crashworthy Traffic Control Devices in Work Zones (9);
4. Caltrans Deputy Directive DD-60 (10);

Institutional Constraints: Most of Caltrans Districts have two different offices for operations and maintenance. This has hindered the use of portable CMSs owned by the districts as described in Section 3.2.

For using Portable ATIS, maintenance personnel need to get the on-site equipment to the site and set them up while the operations personnel have to calibrate and operate the system in an integrated fashion.

Caltrans also discourages the purchase of portable field elements as they are considered vehicles and the agency has restricted purchase of new vehicles. This may constrain the

Districts purchasing portable CMSs and vehicle detection systems to be used in their Districts as needed.

5.3 Description of the Proposed System

Portable ATIS involve several options including systems operated by Caltrans, by contractors or by a Caltrans-contractor team. Typically they may involve;

- Fixed or portable CMS and/or portable HARs to inform travelers of planned and unplanned events on roadways (noting that HARs may only be operated by governmental agencies),

- Communication links from a TMC or local control point to the CMSs and/or HARs to keep traveler messages up to date,

- Portable traffic detection systems to estimate the delay or travel time related to the roadway event,

- Local area communication networks to advise travelers, via a portable CMS, of traffic delays.

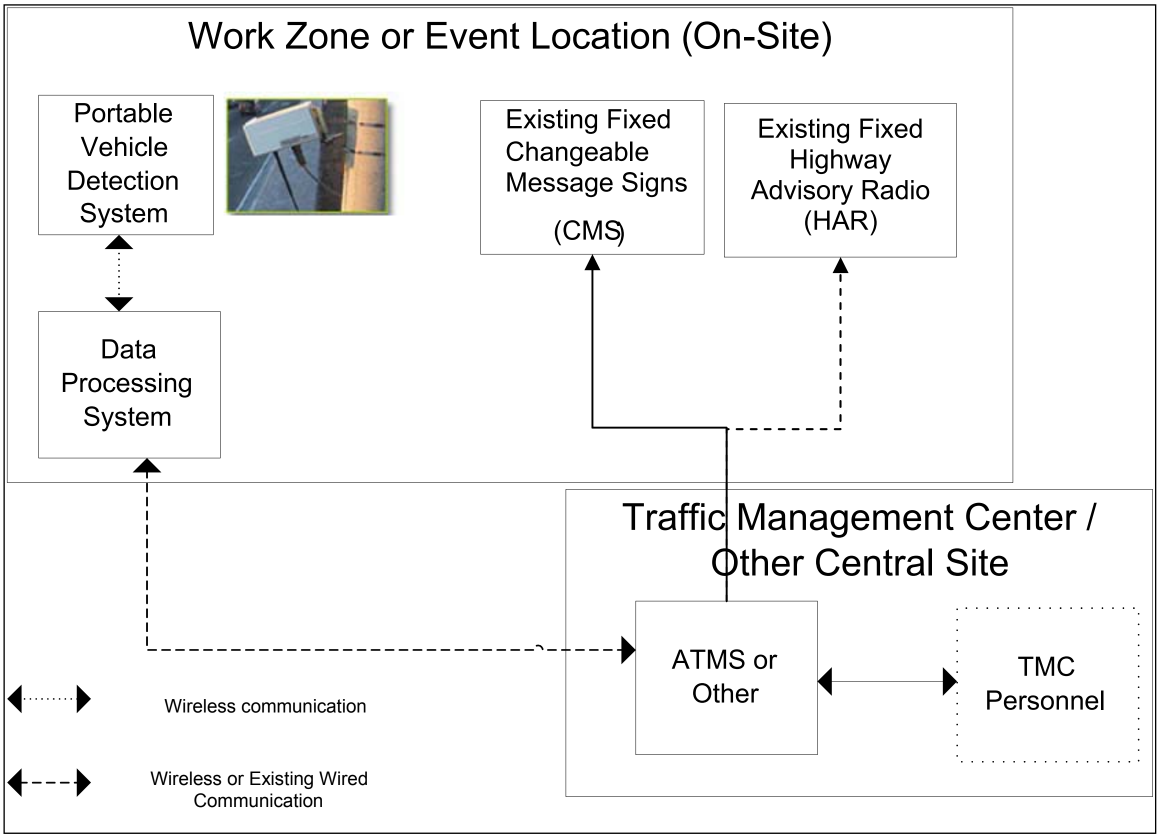
As described above the components may be used in different combinations to provide real-time delay or travel time information related to mid-term and long term planned and unplanned roadway events to the traveling public pre-trip as well as on route. For more details on the proposed system see the introduction section of Chapter 5 and Chapter1.

Under this section, three concepts for Portable ATIS are described.

5.3.1 Concept 1: Portable ATIS using Available Fixed CMS and HARs

As explained earlier, if there are fixed CMSs and HARs in the vicinity of the roadway event, whose functioning will not be affected by the roadway event itself. These may be used instead of Portable CMSs and HARs. It is dependent on the proximity of the fixed ITS elements and the priorities for the use of these elements. Figure 6 depicts this concept. **In this concept, either the portable traffic detection systems or the data processing unit will need an automated interface with a TMC.** As not shown in this figure, the data processing unit may also control the portable CMSs and HARs. But, the data processing units will be connected to the TMC.

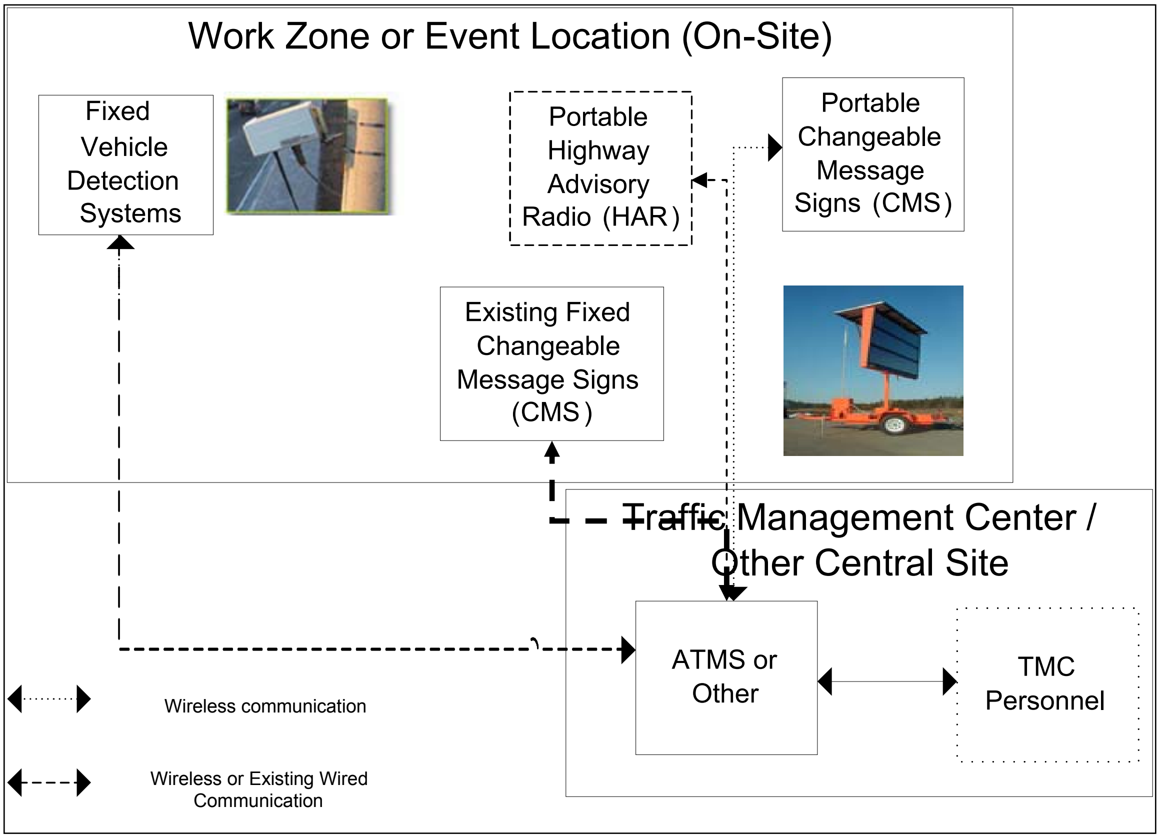
Figure 6. Portable ATIS with Available Fixed CMSs and HARs



5.3.2 Concept 2: Portable ATIS using Existing Fixed Traffic Detection Systems

If there are fixed traffic detection systems at the roadway event location that will not be affected by the roadway event, the existing traffic detection system may be used to estimate delay related to the roadway event using the existing incident detection methods at a TMC. This will eliminate the need for installing a temporary portable traffic detection system. Due to lack of fixed CMSs or HARs in the vicinity of the roadway event, Portable CMSs and HARs will need to be deployed at the event location. These portable ITS elements shall be connected to a TMC which will relay the delay messages on these portable ITS elements. Figure 7 depicts this concept. **In this concept, the portable CMSs and HARs need to have a standardized interface with a TMC.** Fixed CMSs and HARs may be available far from the roadway event location and may be used to inform the upstream traffic of the non-recurring congestion.

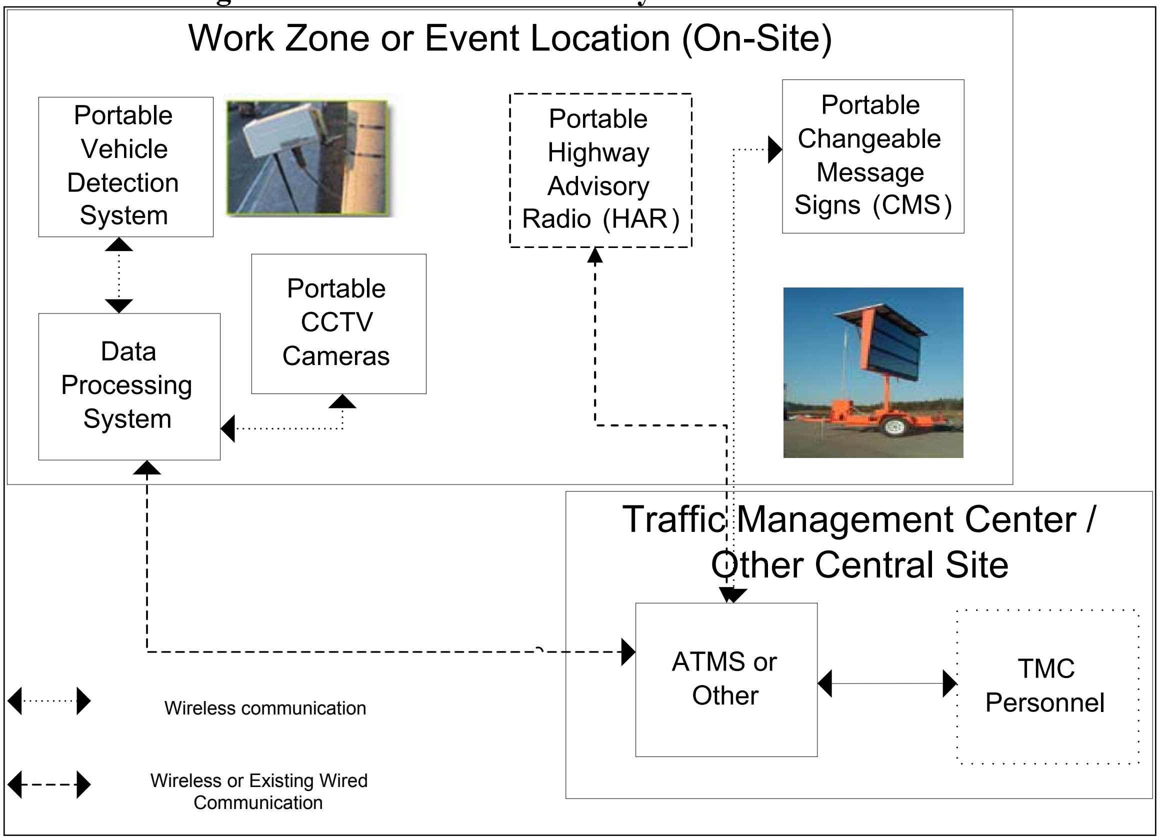
Figure 7. Portable ATIS with Fixed Traffic Detection Systems



5.3.3 Concept 3: Portable ATIS with No Fixed ITS Elements

As shown in Figure 8, Portable ATIS may not have any fixed ITS elements available in the vicinity of the roadway event and use portable ITS elements only in the deployment. But, the Portable ATIS shall still be connected to a TMC so that any relevant safety messages with higher priority may be relayed from the TMC. **But, unlike the figure, the Data Processing System may communicate with the Portable Traffic Detection System and the Portable CMSs / HARs thus eliminating the need for these components to have a standardized interface with a TMC.** Portable CCTV cameras may also be used for message validation as needed.

Figure 8. Portable ATIS with only Portable ITS Elements



5.4 Modes of operation

Proposed Portable ATIS may use existing fixed traffic detection systems instead of a portable vehicle detection system, if available. The communication between the on-site components of Portable ATIS and a TMC or a centralized location may also use existing communication infrastructure such as fiber-optic communication available to the department.

As indicated earlier, HAR is an optional component and may be used when determined to be a required component specific to a site. Portable ATIS may also display just safety messages based on detected stopped traffic, etc. But, Portable ATIS will ideally include safety and delay messages. Delay messages can be in the form of travel times or estimated total delay for a defined roadway segment.

Portable ATIS can be used for events on both rural and urban roadways. The communication needs for rural events are significantly different from urban events. The criteria for determining the need for Portable ATIS to manage a rural event will also be different from an urban event. The following table elaborates on that.

Table 1. Criteria for Portable ATIS Usage

Criteria	**Portable ATIS on Rural Roadways**	**Portable ATIS on Urban Roadways**
1. Estimated Length of the Event	> 1 week	Typically > 1 week. But, short-term events may also need the use of Portable ATIS depending on criteria number 2, 3 and 4.
2. Average Traffic Volume	ADT > 5000	ADT > 7500
3. Estimated Maximum Delay	> 15 minutes	> 30 minutes
4. Estimated Duration of Delays Higher than 15 minutes in a Day.	> 2 hours	> 1 hour
5. Estimated Increased Risk of Crashes Due to the Event	> Medium	> Low
6. Estimated Travel + Set-up + Calibration Time	< five hours	< five hours

Based on the above six criteria, a score between 0 and 5 (Likert scale, 0 is not meeting the criteria and 5 is completely meeting the criteria) may be assigned by the District Operation Office and the TMP Coordinator (i.e., for planned event). If the total score exceeds 15 points, then the use of Portable ATIS should be explored closely and plans should be made for the use of Portable ATIS including the resources and responsible parties within the District and / or on-call contractors.

5.5 User Classes and Other Involved Personnel

This section describes the organizational structure at the District level showing the personnel that are involved in providing traveler information on planned and unplanned events on California highways and is followed by a short profile on the user classes and the interactions among the user classes related to Portable ATIS (i.e., the proposed solution).

5.5.1 Organizational Structure

The organization structure for the proposed solution will remain the same as described in Section 3.5.1. It is expected that a new cooperative procedure will be developed for the District Maintenance and District Operations offices to work together to deploy Portable ATIS, when the district has two different offices for Operations and Maintenance. This new procedure is not expected to alter the organizational structure.

5.5.2 Profiles of User Classes

The users of Portable ATIS can generally be categorized as the stakeholders within the agency (i.e., Caltrans) and non-agency stakeholders. Non-agency stakeholders can be local transportation authorities (e.g., city or county transportation personnel, local EMS personnel, traveling public or local trucking entities). Until Portable ATIS is mainstreamed in California, the potential providers of Portable ATIS are stakeholders (non-agency) as well. The following list of user classes includes agency and non-agency stakeholders.

1. Resident Engineers (RE): Resident Engineer (RE) is the Project Manager at the construction site / project level. Makes TMP changes based upon events. The Resident Engineer keeps the District Transportation Management Center well informed and up to date on the construction progress, delays, closures, and other information which may assist them in the performance of their duties. The Resident Engineer coordinates the use of Changeable Message Signs through the District Transportation Management Center. The Resident Engineer provides guidance to CHP officers performing COZEEP support.

2. Traveling Public – these are the travelers on route that need to be informed about the roadway event and related messages in time for them to make route-choice decisions. Portable ATIS will interact with the traveling public through the portable or fixed changeable message signs, HARs and other regional traveler information interfaces such as 511 and websites. The traveling public would also like to have information on the current roadway events while planning their trip before they are on route. So, Portable ATIS when integrated with TMC will enable that information to be available to the travelers pre-trip as well.

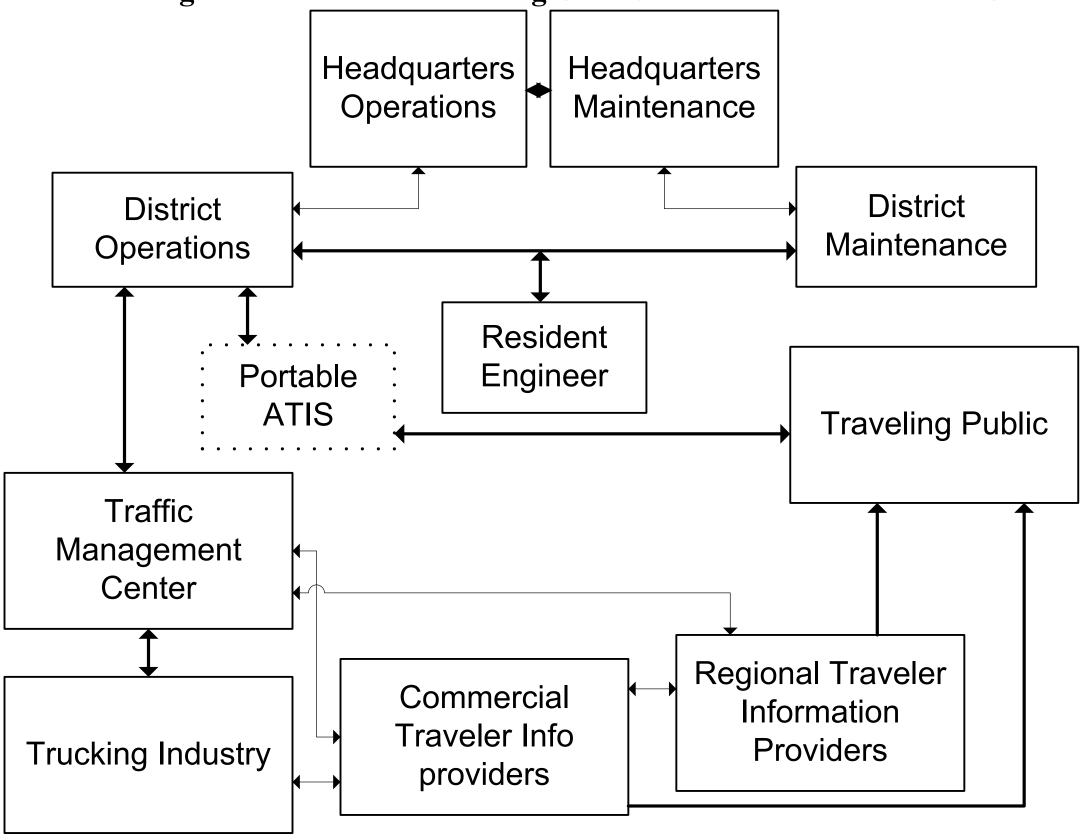
3. Set-up and Maintenance Personnel – District personnel, typically maintenance personnel are responsible for the on-site equipment and set-up. These personnel are expected to be trained in handling roadside equipment and temporary equipment installation. They are also responsible for taking the equipment down and back to the district offices. These personnel will make sure that the system is powered on while it is onsite and house the system during non-use.

4. Operating Personnel – District personnel, typically Transportation Management Center personnel, are responsible for the calibration and actual operations of Portable ATIS. These personnel are experts on the communication needs for fixed or portable field elements.

5. Regional Traveler Information Providers: District and Headquarters personnel that are responsible for 511 and other regional traveler information services (e.g., www.511.org). These personnel are very familiar with the TMC systems (e.g., ATMS). These users will interact with Portable ATIS through a TMC system.

5.5.3 Interactions between User Classes

Figure 9. Interactions among User Classes with Portable ATIS



5.5.4 Other Involved Personnel

As noted above, the Caltrans Division of Operations and Division of Maintenance at the Headquarters influence the policies and procedures for the use of ITS and other systems at the planned and unplanned events. Other involved personnel (i.e., stakeholders) are grouped into the following two categories.

1. Other Agency Stakeholders: Headquarters operations and maintenance personnel provide needed direction and assistance to the Districts' operations and maintenance personnel respectively. Headquarters Division of Operations and Division of Maintenance help set policies and procedures related to technology deployments. So these groups of stakeholders are extremely critical in the early stages of exploring Portable ATIS.

2. Other Non-Agency Stakeholders: Potential providers of Portable ATIS are a critical stakeholder's class as the current offering of systems that provide traveler information around roadway events do not meet the vision for Portable ATIS defined for this effort.

   Commercial traveler information providers may also be interested in utilizing the information that is developed for Portable ATIS. Their interface with Portable ATIS will most likely be through the Transportation Management Center and regional Traveler Information Entity.

   Trucking industry representatives are also affected by the planned and unplanned events on the roadways. The trucking industry may interface with Portable ATIS like the traveling public through the CMS, HAR and additionally through communication from a TMC to their dispatch centers.

5.6 Support Environment

Caltrans Districts are expected to be the primary users of Portable ATIS. One of the objectives of Portable ATIS is to enable integrated region-wide system management. This means that the Portable ATIS should be able to communicate with a central location (i.e., Transportation Management Center) with the least amount of human interaction needed. To achieve this objective, Portable ATIS should have an interface for automated communication with the ATMS or other Advanced Traffic Management Systems used in Caltrans Districts.

Transportation Management Center (TMC) operators use Advanced Transportation Management Software (ATMS) to detect and mange traffic backup from incidents, expedite incident clearance, and manage disasters and special event traffic situations. The ATMS data also feeds the Department's Performance Measurement System (PeMS) used by others within the Department and externally, including researchers and ISPs.

ATMS: Many districts post dynamic ATMS feeds for ISPs to download. Eventually all districts will use the standard 'California-wide ATMS' or Advanced Transportation Management Software. Currently District 04 has a unique system, District 11 utilizes a mix of ATMS with its legacy "freeway management system" software, and the others use various "builds" and feature of the departmental standard ATMS v2. Configurations often differ between districts ATMS feeds linked to the Commercial Wholesale Web Portal.

PeMS: Commercial traveler information service providers can also obtain current and archived information from the freeway Performance Measurement System (PeMS). PeMS is also the Department's main software for deriving freeway system performance measures. It presents the ATMS traffic detection data in a common statewide format (30-second volume & occupancy by lane), and has archival and current data available. PeMS provides both "raw" and "cleansed" versions of the data. The "cleansed" includes 5-minute moving average to correct for traffic fluctuations (11).

CMS Messages: Some districts with ATMS software are able to provide feeds of messages they post on Changeable Message Signs (CMS). Typically these are incident or other delay related messages warning drivers to take specific defensive actions such as accident ahead / merge left / lane closed. Other messages may be advisory; e.g., dense fog / slow vehicles ahead, request motorist assistance as for child abduction alerts, or current travel times between freeway segments. These messages may be embedded in the ATMS, or be separate feeds, depending on the district.

Given this environment, Portable ATIS should have an automated interface with the system used in a TMC for system-wide traffic management. In most of the districts, the TMC uses ATMS v2.

6 Operational Scenarios

A scenario is a step-by-step description of how the proposed system (i.e., Portable ATIS) should operate and interact with its users and its external interfaces under a given set of circumstances. The scenarios tie together all parts of the system, the users, and other entities by describing how they interact. Scenarios may also be used to describe what the system should not do.

Scenarios play several important roles. The first is to bind together all of the individual parts of a system into a comprehensible whole. Scenarios help the readers of a Concept of Operations document understand how all the pieces interact to provide operational capabilities. The second role of scenarios is to provide readers with operational details for the proposed system; this enables them to understand the users' roles, how the system should operate, and the various operational features to be provided.

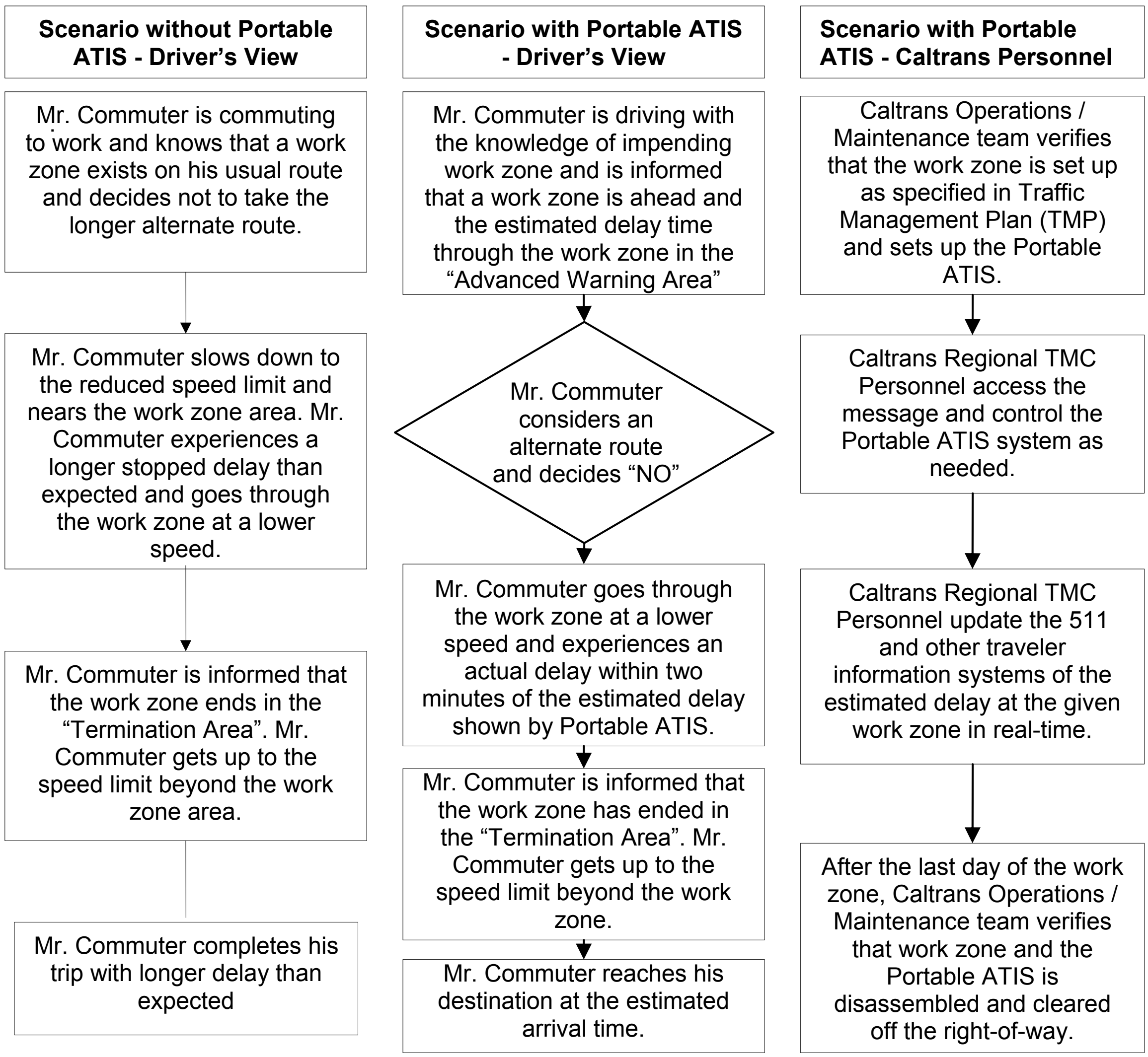
Scenarios are organized below in sections, each describing an operational sequence that illustrates the roles of the system, its interactions with users, and interactions with other systems.

6.1 Scenario 1: Long-Term Planned Events

Long-term events are defined as events that last longer than one month. These long term events are typically expected to be planned (i.e., construction zone). The following example scenario describes the use of Portable ATIS in the view of customers (i.e., driving public) and the providers (i.e., Caltrans Districts). In the scenario presented below, it is assumed that Caltrans districts will own and house Portable ATIS. It should be noted that an on-call contracting mechanism may be feasible for an outside entity to provide Portable ATIS equipment as well as set-up calibration services. In this scenario, a description of activities when Portable ATIS is not used is also provided for quick comparison.

The primary advantage of the use of Portable ATIS is that the driving public is informed about the delays related to roadway events (i.e., non-recurring congestion); pre-trip as well as on-route thus allowing them to make route selections and trip plans with all of the information. Use of portable ATIS will also enable system wide traffic unlike the current situation where no on-site equipment is connected to a TMC.

Figure 10. Scenario 1: Long Term Planned Event



6.2 Scenario 2: Mid-Term Planned Events

Roadway events referred to as mid-term events are events that last between two weeks and a month. Mid-term events may be planned or unplanned. Mid term planned events are typically special events (e.g., road closure related to festival in an area) or a relatively smaller construction work on the roadway. The scenarios described below are a mid-term work zone. The first scenario is a mid-term construction zone on an urban roadway while the second scenario is a similar event on a rural highway.

Figure 11. Scenario 2: Mid-Term Planned Event Scenario 1 on Urban Roadway

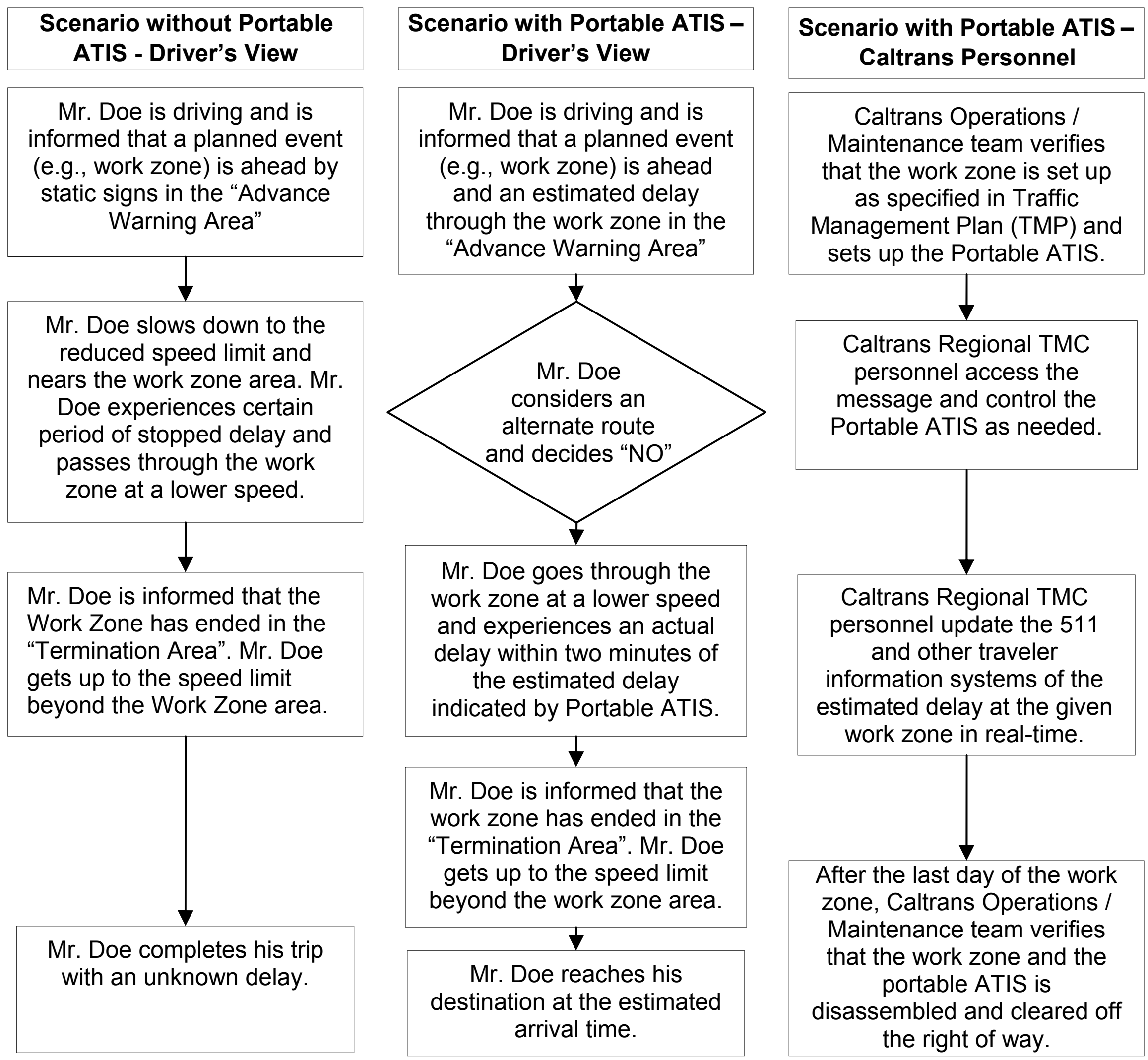
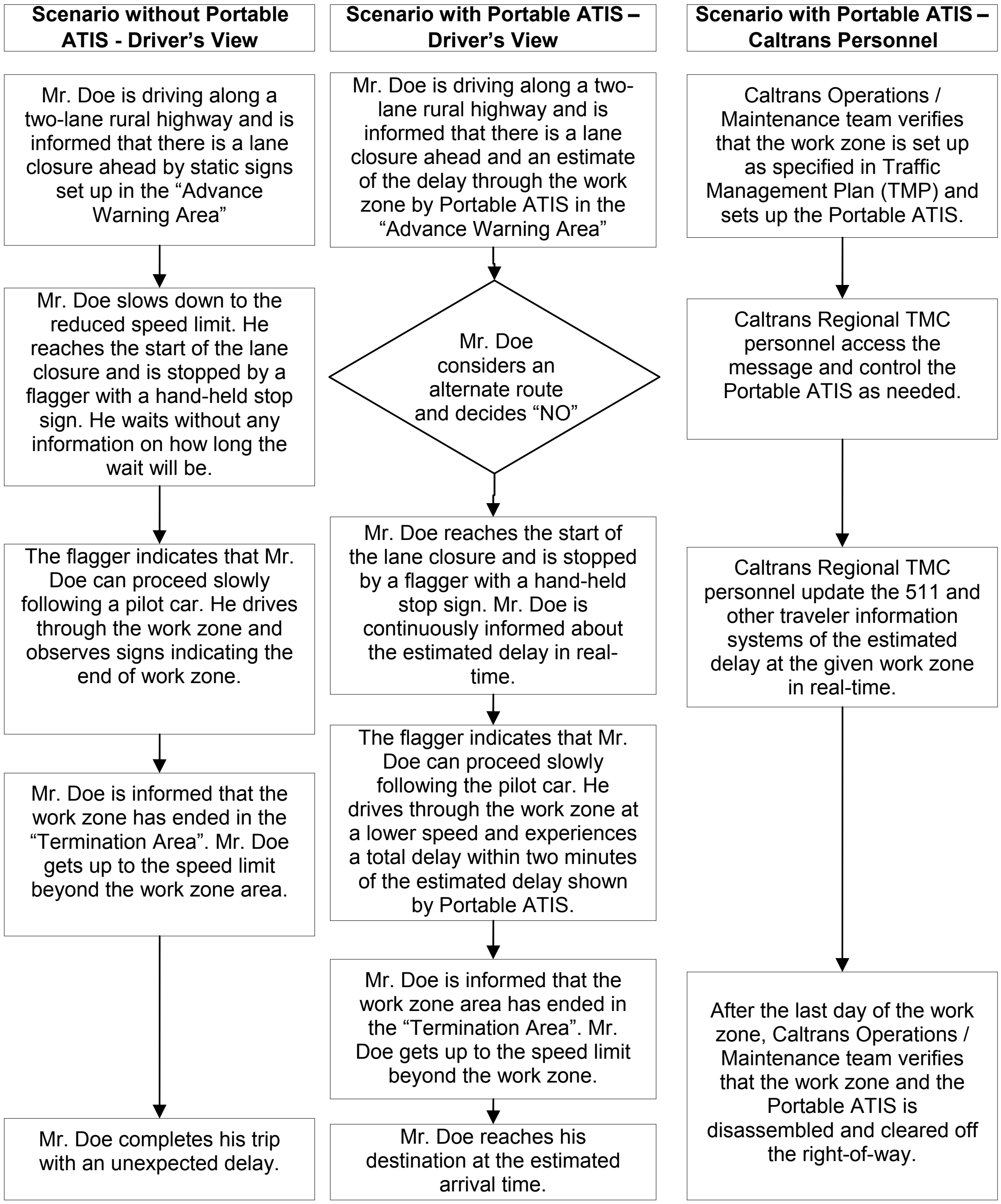


Figure 12. Scenario 2: Mid-Term Planned Event Scenario 2 on Rural Roadway

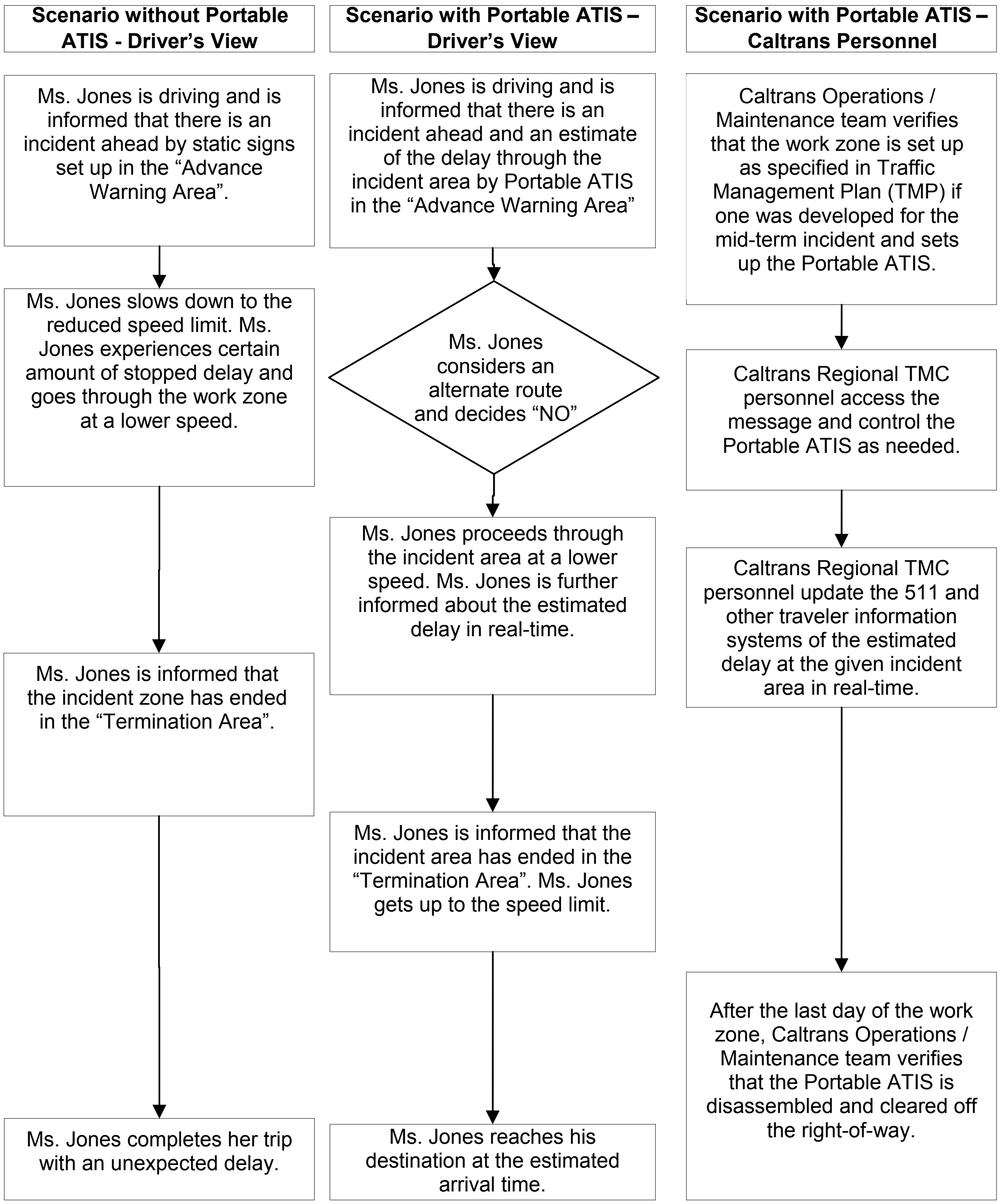


The primary difference between the two scenarios presented here is that the rural construction zone involves stopping all the traffic (i.e., a two lane rural highway where one lane is closed and the remaining lane is used by traffic in both directions alternatively). It has been documented that the stopped traffic is perceived much more negatively by the traveling public especially when there is no information on why they are stopped and how long they are expected to wait in the stopped traffic. Portable ATIS will enable the drivers to be informed about the expected wait time when they are already in the stopped traffic as well as inform them in advance so that they can take an alternate route because a TMC will be connected to the Portable ATIS and may be able to inform the drivers up stream using their fixed ITS infrastructure.

6.3 Scenario 3: Mid-Term Unplanned Events

Mid-term unplanned events are typically incidents (e.g., mudslides). No Traffic Management Plan (TMP) may be put together for an unplanned mid-term event. So, a Resident Engineer or TMP coordinator may be involved in the use of Portable ATIS for these events.

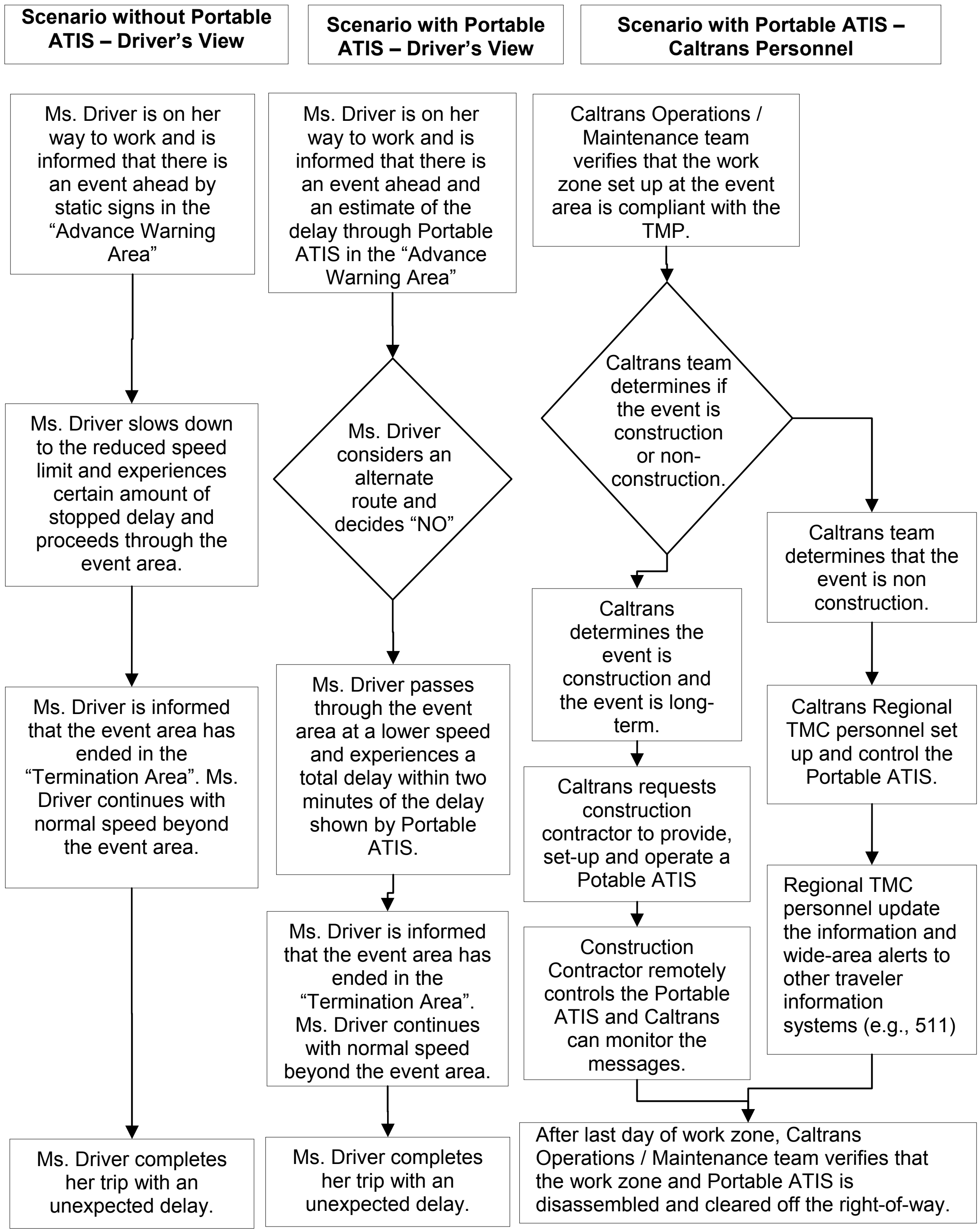
Figure 13. Scenario 3: Mid-Term Roadway Incident Scenario



6.4 Scenario 4: Short-Term Planned Events

Short-term events are defined as roadway events that last up to two weeks. Short-term events may be planned or unplanned. Typically short-term unplanned events involve roadway crashes, hazardous material spills and other roadway events resulting in temporary capacity reductions. Short-term planned events are typically special events (e.g., lane closure due to a sports event) and other maintenance activities on roadways (e.g., chip-sealing a roadway segment, winter preparation of bridge decks, etc.).

Figure 14. Scenario 4: Short-Term Planned Event Scenario



7 Summary of Impacts

This chapter describes the operational impacts of Portable ATIS on the traveling public, Caltrans personnel and other stakeholders of Portable ATIS. This information is included in the Concept of Operations document to allow all the users to prepare for the changes that will be brought about by Portable ATIS during the transition to Portable ATIS.

7.1 Operational Impacts

This section is divided into subsections to describe the anticipated operational impacts on the user, development, and support or maintenance agency or agencies during operation of the proposed system.

7.1.1 Interfaces with Transportation Management center (TMC) and Other Systems

As discussed in the earlier chapters, Portable ATIS shall be connected to a Transportation Management Center (TMC) to enable system-wide management of traffic. For this purpose, the Portable CMSs that are owned and housed at the Caltrans Districts need a standardized interface with the Advanced Traffic Management System (ATMS) at the TMC. Advanced Traffic Management Systems in most of the Caltrans districts is ATMS v2. The Portable Traffic Detection Systems or the Data Processing Unit also needs to have a standardized interface with a TMC depending on where the Data Processing Unit is placed. If the data is to be transmitted to a TMC by the Portable Traffic Detection Systems, these traffic detection systems need to have a standardized interface to a TMC. If a Data Processing Unit is placed on the location to gather and process the information from the traffic detection systems and to control messages on the Portable CMSs and HARs, the Data Processing unit will need a standardized interface with a TMC.

In the current situation, there is no standardized interface between the Portable CMSs, the Portable Traffic Detection Systems or Data Processing Units and a TMC. Portable ATIS will include one or both of these interfaces depending on the mode of operation and configuration.

7.1.2 Changes in Procedures

Portable ATIS will need to be set-up and calibrated at the event location. Typically, this is expected to be performed by the maintenance personnel. The office of maintenance is also expected to house Portable ATIS when it is not in use. The Operations personnel will be responsible for operating Portable ATIS and utilizing the data from Portable ATIS for the system-wide management of traffic.

At Caltrans districts with two separate offices for maintenance and operations, a cooperative procedure may need to be established for the deployment of Portable ATIS at the roadway events. This may include clear definitions of roles and the responsible personnel for each task in the deployment of Portable ATIS.

7.1.3 Use of New Data Sources

The data from the Portable Traffic Detection Systems as well as the processed information will be sent to ATMS at the Transportation Management Center. ATMS can use this information to determine whether any of the fixed CMSs or HARs in the vicinity may be used to inform the traveling public affected by the particular roadway event. This may include informing the traveling public further up stream to encourage using alternative routes as well as making the delay or travel time related information available through regional traveler information systems (e.g., 511) so that travelers can plan their trip better before they start the trip.

7.1.4 New Modes of Operation

As detailed in Table 1 in Section 5.4, the use of Portable ATIS or other existing ITS elements in the vicinity may be determined by the District Traffic Operations personnel. A number of configurations of Portable ATIS are possible as discussed in Chapters 4 and 5. A specific configuration may be standardized for a specific district so that the personnel can be trained and prepared to deploy Portable ATIS when determined it is needed by the District Operations personnel.

7.1.5 Changes in Operational Budget

As discussed in Chapter 3, the existing Caltrans policy restrictions on the ownership of vehicles (i.e., all portable equipment are considered vehicles as well) by the agency may not allow Portable ATIS to be owned and operated by the Districts. In the case that a specific district is not able to own a system (i.e., Portable ATIS), they may enter into an on-call contract with a Portable ATIS provider who may be called upon when a specific roadway event is determined to need the deployment of Portable ATIS. This on-call contract may need to have a minimal number of usages. So, the Districts will need to set aside resources for Portable ATIS on an annual basis.

7.1.6 Changes in Operational Risk

Use of Portable ATIS will inform the traveling public of roadway events in time for them to manage their trip better thus leading to less aggravated drivers near the event location as well potentially lesser congestion at the roadway events when alternate routes are available. This may result in safer clearance or operations of the roadway event.

7.2 Organizational Impacts

This section is divided into subsections to describe the anticipated organizational impacts on all of the users of Portable ATIS during its' operation. These impacts include the following:

- Identification of responsibilities for Portable ATIS deployments at the district level. This may potentially include modification of current responsibilities;
- Training the responsible personnel in setting up and calibrating the on-site Portable ATIS equipment is critical to the successful usage of Portable ATIS at appropriate roadway events;
- Identification of TMC personnel that will be responsible for coordination of the use of Portable ATIS; and
- Identification of TMC processes that will be altered or affected by the use of Portable ATIS will need to be completed by the TMC personnel and a set of guidelines for the District personnel will be needed for continuity of the knowledge.

7.3 Impacts during Development

This section describes the anticipated impacts on the user of Portable ATIS. These impacts may include the following:

- Caltrans HQ Operations, HQ Maintenance, District Operations, and District Maintenance personnel need to be involved in developing Portable ATIS guidelines and other documents related to the use of Portable ATIS;
- Caltrans Districts have been solicited to participate in a demonstration effort to test Portable ATIS. Further refined Portable ATIS will need to be tried through demonstrations at representative districts. CCIT team will provide support to these tests; and
- Districts where demonstrations of Portable ATIS are conducted may need to dedicate some resources and personnel from Operations and Maintenance for the duration of the demonstrations.

None of the systems in the current offering of smart work zone systems in the market place meet all of the user needs described in this document. So, the current set of systems that are typically not connected or controlled by a TMC and portable CMSs will continue to be used to provide messages that are not dynamic or real-time. It is expected that

Portable ATIS as defined for this effort will be available from potential providers in the near future.

8 Analysis of the Proposed System

This Chapter provides an analysis of the benefits, limitations, advantages, disadvantages, and alternatives and trade-offs considered for Portable ATIS.

8.1 Summary of Improvements

This Section provides a qualitative summary of the benefits to be provided by Portable ATIS. This summary includes the below items, as applicable. In each case, the benefits should be related to deficiencies identified in the earlier Chapters.

8.1.1 New Capabilities

Portable ATIS will enable the portable field elements to be connected to a Transportation Management Center (TMC) using a standardized interface with ease. This will also allow a TMC to manage the roadway event using a system-wide approach. This will enable the traveling public to be notified of road events in time so they can plan their trips with real-time information. In summary, the following new capabilities will be provided by Portable ATIS.

- A system to provide dynamic information on roadway events (Portable ATIS) will have set-up and calibration time less than five hours;
- Portable ITS field elements (i.e., Portable CMS or HAR) will be connected to a TMC;
- Data collected by the portable traffic detection system and processed data by the data processing unit will be available to the TMC personnel to develop system-wide traffic management strategies as needed; and
- Use of Portable ATIS shall be considered as early as the TMP process and the plan for the usage will be included in the TMP for construction related roadway events.

8.1.2 Enhanced Capabilities

Messages shown on Portable CMS in the current situation are not dynamic or real-time. Most of the time generic messages are displayed regarding the roadway event (e.g., work zone ahead, prepare to stop ahead, etc.). Portable ATIS will enable dynamic, real-time messages on delay, travel time and safety to be provided to the traveling public in time.

8.1.3 Deleted Capabilities

No existing capabilities are proposed to be deleted by Portable ATIS.

8.1.4 Improved Performance

Portable ATIS will result in the following improvements:

- Better mobility through better management of traffic around the roadway event;
- Better mobility through better management of system-wide traffic using the fixed ITS elements located across the region;
- Better regional traveler information provided to the traveling public pre-trip as well as on route;
- Safer work zones and incident areas due to less aggravated drivers;
- Better customer (i.e., the traveling public) satisfaction as a result of better traveler information and potentially reduced non-recurring congestion.

8.2 Disadvantages and Limitations

This Section provides a qualitative summary of disadvantages and limitations of the Portable ATIS.

Disadvantages

1. Use of Portable ATIS will need additional resources (either from Districts or an on-call contractor) for setting up and calibrating the system.
2. District maintenance personnel responsible for setting up and calibrating the system will need to be trained. This may not be needed if an on-call contractor is used for Portable ATIS deployments.
3. District operations will need to have TMC personnel with expertise to have Portable ATIS connected to a TMC as well as the regional traveler information systems. Getting Portable ATIS information to the regional traveler information system may need to go through ATMS and / or PeMS.

Limitations

1. It is desired that Portable ATIS is capable of being connected to a TMC when there is no cell phone coverage. But, all of the Portable ATIS offered may not have this option as non-cell phone based communication link to a TMC is significantly expensive.

2. It is desirable that all of the portable components on-site communicate with a TMC. But, Portable ATIS may have a data processing unit on-site that

communicates with the other on-site components of Portable ATIS as well as a TMC.

3. Portable ATIS is envisioned to be used at all roadway events. But, it may not be possible to use Portable ATIS at roadway events that may last less than one-week depending on certain factors such as the traffic volume through incidents and others as described in Chapter 5 of this document.

8.3 Alternatives and Trade-offs Considered

As described in Chapter 5, there are three different concepts that apply to this Concept of Operations Document. Other alternative to Portable ATIS is using static signs that advise the driving public of an impending roadway event. These static signs have very limited effectiveness in influencing driver behavior around occasional roadway events. A recent study (12) surveyed 28 highway agencies and documented the following:

When asked about their perception of the effectiveness of static warning signs for occasional hazards (SWSOH), 18 percent of survey respondents thought these signs were effective, 7 percent thought the signs were ineffective and 4 percent were not sure about the answer. ***The majority of respondents (71 percent) viewed the signs as "somewhat effective."***

As described in Chapter 5, some of the roadway events may not need Portable ATIS for various reasons such as shorter duration of the roadway event, smaller impact of the roadway event, etc. So, the District personnel will methodically determine whether the use of Portable ATIS is warranted or not.

9 Definitions, Acronyms and Abbreviations

Definitions:

Portable ATIS - Portable ATIS is a portable system to provide critical real-time safety and delay information on non-recurring congestion caused by planned or unplanned events to the travelers that are on route as well as make this information available to District Operations to use for system-wide regional traffic management.

Acronyms

ATIS	–	Advanced Traveler Information Systems
ATMS	–	Advanced Traffic Management Systems
Caltrans	–	California Department of Transportation
CMS	–	Changeable Message Signs
CCTV	–	Close Circuit Television Cameras
HAR	–	Highway Advisory Radio
IT	–	Information Technology
ITS	–	Intelligent Transportation Systems
PeMS	–	Performance Measurement System
TMC	–	Transportation Management Center

10 Appendices

Appendix A: Deploying Portable Traveler Information Systems: Supporting Information for the Concept of Operations by Western Transportation institute examines the options for communications among different components of Portable ATIS and the communication between Portable ATIS and a TMC.

Deploying Portable Traveler Information Systems

Supporting Information for the Concept of Operations

by

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AM	Amplitude Modulation
ATIS	Advanced Traveler Information System
BGAN	Broadband Global Area Network
Caltrans	California Department of Transportation
CCIT	California Center for Innovative Transportation
CCTV	Closed Circuit Television
CDMA	Code Division Multiple Access
CMS	Changeable Message Sign
DSRC	Dedicated Short Range Communications
EDGE	Enhanced Data rates for Global Evolution
EV-DO	Evolution Data Optimized
FAP	Force Account Project
FCC	Federal Communications Commission
FM	Frequency Modulation
GEO	Geostationary Earth Orbit
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
HAR	Highway Advisory Radio
IP	Internet Protocol
ISM	Industrial, Scientific, Medical Band
ISP	Internet Service Provider
ITS	Intelligent Transportation System
LAN	Local Area Network
LEO	Low Earth Orbit
LOS	Line-of-Sight
LPFM	Low Power Frequency Modulation
MAG	Mini Adjustable Graphic
PDA	Personal Digital Assistant
RWIS	Road Weather Information System
PATIS	Portable Advanced Traveler Information System
PCS	Personal Communications System
PIO	Public Information Officer
POTS	Plain Old Telephone Service
RF	Radio Frequency
RSAC	Remote Sensing Applications Center
SHOPP	State Highway Operation and Protection Program
TIS	Travelers' Information Stations
TMC	Traffic Management Center
TMS	Traffic Management System
UHF	Ultra High Frequency
USFS	United States Forest Service
VHF	Very High Frequency
VPN	Virtual Private Network

VSAT	Very Small Aperture Terminal
WiFi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WTI	Western Transportation Institute

EXECUTIVE SUMMARY

This document is intended for use in the Concept of Operations document being prepared by the California Center for Innovative Transportation (CCIT). It is not intended for use as a standalone concept of operations. The purpose of this document is to addresses the specific communication technologies that typically would be used in a Portable Advanced Traveler Information System (PATIS). It considers various options that could be used for:

- Communication between a Traffic Management Center (TMC) and a work zone.
- Communications among various links in a work zone (e.g., to provide travelers information on estimated arrival time of a pilot car).
- Communication from a TMC or local work zone control point to a Changeable Message Sign (CMS) and/or Highway Advisory Radio (HAR)
- Portable HAR systems to provide current, detailed information to travelers regarding road construction, traffic delays, highway obstructions/closures, etc.

The document also considers numerous communications technologies which could be used with PATIS systems including:

- Radio frequency (RF) systems in frequency bands from Very High Frequency (VHF) high-band through 900 MHz (licensed and unlicensed) for local area communications.
- Cellular or satellite based communications (Low Earth Orbit (LEO) and Geostationary Orbit (GEO)) for longer distance communications or communications in areas where other RF communications are not viable.
- Amplitude Modulation (AM) and Frequency Modulation (FM) HAR options.

Portable Advanced Traveler Information Systems are typically comprised of one or more of the following components:

- Fixed or portable CMS
- Portable Highway Advisory Radios (HARs, also known as Travelers' Information Stations or TISs)
- Data Processing System
- Portable Vehicle Detection Systems
- Portable Road Weather Information Systems (RWIS)
- Communication links from a TMC or local control point to the CMSs and/or HARs to keep traveler messages up to date,
- Local area communication networks to advise travelers, via a portable CMS, of traffic delays (e.g., approximate arrival time of a pilot car).

This document examines the application of several of these components as part of a PATIS system in a case study that covers a landslide on SR 96 in Humboldt County, California. The various communication options are applied to this case study as an example. In particular, communication coverage of the landslide site and the surrounding area is addressed using propagation analysis tools for each of the RF options and satellite coverage of the area is demonstrated using Google Earth maps.

The results of this project illustrate how the various PATIS components and the application of various communication alternatives addressed above might apply to any work zone activity to provide both the traveler and the TMC and work zone control site with current information.

Each technology discussed in this document has benefits and drawbacks associated with it. There is no single technology that will address all communications requirements at any given location. Caltrans must determine the need for communications with a remote location. This need will assist Caltrans in determining the most appropriate communications technology to employ.

It is also important to note that the information presented in this document is not intended to replace sound engineering judgment and proper design performed by a qualified radio systems engineer.

1. INTRODUCTION

Advanced Traveler Information Systems (ATIS) are routinely used for traffic management and traveler information applications in rural and urban work zones or as part of incident management. There are two flavors for each: fixed and portable. Some technology components of fixed and portable ATIS include:

- Highway Advisory Radios (HAR)
  - HARs are available in both AM and FM frequencies
  - Fixed site HAR – Typically deployed along major highways to deliver detailed highway/traffic information to travelers
  - Portable HAR – Typically deployed near work zones to inform travelers of delays, closures, alternate routes, etc.
- Changeable Message Signs (CMS)
  - Fixed site CMS – Typically deployed along major highways to deliver general highway/traffic information to travelers
  - Portable CMS – Typically deployed near work zones to inform travelers of delays and to advise them to tune into a HAR frequency for more detailed information
- Data Processing System
  - System which receives the traffic data from the vehicle detection system and calculates estimated delays and related alarms and has the capability to generate messages to display on the CMS
  - To provide TMC staff with estimated delays and related alarms
- Portable Vehicle Detection Systems:
  - Mobile systems that detect and monitor traffic and assess traffic conditions in real-time in a work zone area or incident location
  - Portable systems that can be easily moved to new locations and recalibrated to accommodate construction staging and traffic flow adjustments/changes
- Portable Road Weather Information Systems (RWIS)
  - Mobile systems provide local weather information in the vicinity of the work zone or the incident location
  - Mobile systems may be used to monitor weather on-site for work staging/planning and safety purposes
- Communication links from a TMC to a fixed site or work zone
  - To control CMSs or HARs
  - To observe traffic via a Closed Circuit Television (CCTV) camera
  - To receive data from a work zone or incident location (e.g. photo of a highway disruption)
  - To communicate with on-site personnel, Caltrans or contractor
- Communication between an on-site supervisor and a portable HAR and/or CMS
  - Local Area Network (LAN), e.g. to provide information on the location of a pilot car and its predicted arrival at the end of a work zone or incident location
  - Cellular or Geostationary (GEO) satellite connection to a portable HAR and/or CMS
- Cellular access to 5-1-1 for detailed traveler information

- Future traveler information technology - Dedicated Short Range Communications (DSRC) system to provide data communications between a roadside site and a laptop computer or Personal Digital Assistant (PDA) in a vehicle.

In the deployment of Portable Advanced Traveler Information Systems (PATIS) for the purpose of informing travelers about both urban and rural work zones or highway emergencies (such as avalanches, for example) there are several considerations:

- In a typical PATIS application, system components (i.e. traffic detection sensors and CMSs) should be placed in key locations for traffic data acquisition and message display at locations near the work zone or incident. Systems need to be portable so that they can be placed at critical locations.
- Traffic detection systems should be deployed at appropriate locations upstream and downstream of the work zone or incident. Systems may require a Changeable Message Sign (CMS) or other form of driver notification that a HAR (Highway Advisory Radio) is present and the frequency on which it is transmitting.
- The detection systems collect traffic data pertaining to traffic volumes, speeds and occupancy passing through the work zone or incident location. An on-site data processing unit controls the PATIS components and associated tasks such as processing data from the detection system, message generation and posting. Additionally, it may transmit the data to the regional Traffic Management Center (TMC).
- Portable RWIS systems collect local weather information in the vicinity of the work zone or incident. The data may be transmitted to the TMC.
- Two-way communications between the TMC and the processing unit are required as the District TMC will need to control and access the PATIS. The TMC will need to track, log and change the messages that are displayed by the PATIS units. Bi-directional communications will also enable the TMC to acquire and disseminate real-time updates on the current traffic situation in the work zone or at the incident location, e.g., predicted arrival times of a pilot car at the ends of a work zone.
- Portable systems must be rugged to reduce the possibility of damage by weather or local construction activities.
- Security of portable systems may be an issue during hours when construction is not active.

1.1. TMC to Site Communication

One of the more critical aspects is TMC access to the PATIS site for operations and observation purposes. In some areas, where there is access to the State's 800 MHz Public Safety network or to telephone carrier landline services, this may not be a problem. (We note, however, that landline options would rarely be viable at a construction site unless, perhaps, the site was in an urban area and/or the length of construction period was quite long.) On the other hand, even if those services are available they may not provide the capability for sufficient digital bandwidth, particularly for CCTV cameras to observe traffic conditions. Accessing the State's 800 MHz public safety network may also be somewhat difficult as it was designed primarily for voice communications. Thus other viable options need to be considered.

1.1.1. Cellular Options

In many locations along California highways, cellular services with useful digital bandwidth are currently available (note, however, that there are numerous sites in California's mountainous terrain, for example, where cellular/Personal Communications System (PCS) service is not available) , or in the process of being implemented, by cellular or PCS carriers such as AT&T and Verizon. These include:

- 1xRTT (CDMA2000 1xRTT) is a 2.5G Verizon cellular service with a data rate of 144 kb/s uplink and download and is currently available in most of California.
- EVDO-1X (technically called CDMA2000 1xEV-DO) is scheduled to be available at Verizon Wireless sites in California by the end of 2008. EvDO-1X is a wideband cellular (3G) "data only" service with a theoretical data rate of 2.4 Mb/s uplink and downlink. Figure 1 is a map illustrating Verizon's EV-DO coverage of California. Blue indicates EV-DO availability [1].

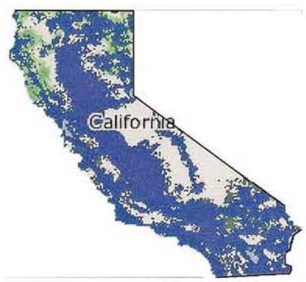


Figure 1: EV-DO Coverage in California (in Blue) - Courtesy of Verizon Wireless

- Global System for Mobile Communications (GSM) is a 2G cellular/PCS service from which GPRS and EDGE were developed. Low data rate (9.6 kb/s) relative to General Packet Radio Service (GPRS) and Enhanced Data rates for Global Evolution (EDGE).
- GPRS, a 2.5G packet-oriented mobile data service, available to users of GSM cellular service, with a data rates from 56 to 114 kb/s.
- EDGE is an Edge Wireless (recently acquired by AT&T) enhanced GPRS PCS service. Data transmission rates are 384 kb/s for EDGE due to the use of a new modulation technique and error-tolerant transmission methods [2]. This service will also be available in most of California by the end of 2008.

<u>Benefits associated with cellular technology:</u>

Whenever continual access (adequate field strength) is available, high data rate cellular/PCS technologies (1xRTT, EV-DO – 1X, GPRS or EDGE) can provide excellent communications for any type of field element, particularly CCTVs.

<u>Drawbacks associated with the use of this technology:</u>

In irregular terrain, such as mountainous areas, field strength can vary significantly along highways. Hence, digital cellular area coverage may limit the number of field elements that can be served. PCS is somewhat more limited in coverage than cellular due to higher frequencies. For dial-up services, high volume traffic may limit access. Monthly service charges also apply.

Range of use:

- 1xRTT, EV-DO and GPRS – 20 miles line-of-sight (LOS) to the cell tower
- EDGE – 15 miles LOS to the cell tower

When/How this technology should be used:

Whenever cellular/PCS coverage is adequate for the intended use. Applicable for rapid deployment and direct TMS to TMC communications.

When/Why this technology would not be used:

When cellular coverage is marginal or non-existent.

Installation/Maintenance issues/considerations:

Since cellular service can vary significantly in irregular terrain, several on-site field strength samples should be taken at different times of day at exact locations where equipment will be deployed to determine field strength continuity. An on-site field strength analysis should also be conducted to determine adequate continuous field strength. Installation of the cellular modem(s) is simple. Typically, high gain antennas can be readily mounted on a portable pole. Physical maintenance of the equipment hardware (e.g., exchanging a device or antenna) can be performed by staff. Technical support would be provided by the service provider.

Typical costs for equipment hardware:

- Cellular modems: $300 – $950 - hardened modems available in this price range
- Yagi antenna: $200–$300

Typical costs for services:

These services would be viable for a connection to a PATIS site and the costs are relatively reasonable. Note that service is required for each PATIS unit and the TMC.

- Verizon (EV-DO-1X; 1xRTT) - $59.99/mo, unlimited access [3]
- AT&T (EDGE) - $49.99/mo, unlimited access [4]

Summary:

Cellular is a viable choice for communications, particularly when other services are unavailable and cellular coverage is good. Data rates for EV-DO, 1XRTT, EDGE, and GPRS are all greater than 100 kb/s, which make these cellular technologies adequate for any high data rate requirement. EV-DO is data only but operates on a CDMA signal so will be available wherever CDMA voice service is available as service provider data networks expand [5]. Note that in the event of a major incident, cellular traffic congestion, primarily in voice systems, may be significant and cause interruptions in cellular availability.

1.1.2. Satellite Options

There are various flavors to satellite options which are introduced and briefly discussed in the following sections. Not all satellite options presented are viable options for PATIS systems and use.

1.1.2.1. Satellite Alternatives

Multiple satellite options are available; however, not all are appropriate/designed for use in a portable application. The most common satellite options are

- Geostationary Earth Orbit (GEO) satellite systems
  - Very Small Aperture Terminal (VSAT) systems,
  - Intelsat
  - Inmarsat
  - Satellite Internet Service Providers (ISP)
    - WildBlue
    - HughesNet
- Low Earth Orbit (LEO) satellite systems
  - Iridium
  - Orbcomm
  - Globalstar

Portable GEO and LEO satellite systems are available. Each option, LEO or GEO, has associated benefits and drawbacks. GEO systems use fixed satellites which appear stationary from the Earth's surface. For this reason, precise dish alignment and antenna positioning are required for GEO satellite systems. This task can be very challenging and is non-trivial, particularly for the non-technical user. GEO satellites tend to have a relatively large coverage area; however, there are areas where GEO will not work. LEO satellites are located closer to the Earth's surface; therefore coverage may be intermittent as the LEO footprint will vary depending upon the rotation of satellites in orbit, particularly in mountainous terrain. Deployment of LEO systems is fairly straightforward as it is not necessary to point the antenna. LEO systems would be a viable option in locations where GEO systems would not work assuming that an intermittent, low data rate application would suffice and be preferable to no coverage of a particular location. GEO and LEO systems are discussed in detail in sections 1.1.2.2 and 1.1.2.4 respectively. One must note that while many portable satellite systems are available, obstruction of the sky will cause problems in many areas in California due to terrain and vegetation. Additionally, satellite systems can be expensive to purchase and operate. Applicability of any system will depend upon the need for information from a given location within the state.

1.1.2.2. Geostationary Earth Orbit (GEO) Satellite Systems

GEO satellites are placed in the equatorial plane at a distance of 22,000 miles from the earth's surface, and their orbital period is equal to the earth's rotation period. Hence, the GEO satellites appear stationary from the earth's surface. GEO satellites provide greater bandwidth capabilities and are best suited for fixed applications. This class of satellite system includes Very Small Aperture Terminal (VSAT), Intelsat, Inmarsat, and Satellite Internet Service Providers such as HughesNet and WildBlue, Those GEO systems that operate in the bands above 10 GHz (K_u and K_a) may be affected by rain or snow. The K_u band, however, is mildly affected and interruptions are infrequent and of short duration.

HughesNet is an example of a GEO system that provides coverage of almost the entire State of California. Note that aligning an antenna dish to a satellite, however, is non-trivial and may be time consuming and problematic, particularly for an inexperienced user. Self aligning dish antennas are available but their cost is significant (e.g. MotoSAT Datastorm G74 priced at

$5,295 installed [6]). For a portable ATIS system that will be used at multiple work sites, however, a self-aligning dish may be acceptable.

1.1.2.2.1. VSAT Applications

VSAT Systems uses Telstar 14 and G-28 (IA-8) satellites located at 63° W and 89° W longitude respectively [7]. Typically, VSATs are relatively small and, usually, very robust. Dish antennas are roughly 3 to 4.5 feet in diameter and the entire dish mechanism weighs less than 150 pounds. Smaller units may be available in the near future. VSAT can handle 3 Mb/s uplink and 1.5 Mb/s down, which might make them a viable TMS to TMC link for several field elements in a small LAN, for example.

1.1.2.2.2. Intelsat

Intelsat is a network of 53 geostationary satellites, 8 teleports and more than 20,000 miles of terrestrial fiber [8]. Intelsat was the first commercial global satellite communication system launched in 1965 and provides remote site and VSAT support through Intelsat General Corporation. For point-to-point uplink service Intelsat provides 64 kb/s to 2 Mb/s (higher downlink rates) using C band and K_u band satellite capacity [9]. Intelsat VSAT dishes can be in the 3 to 4 feet diameter range. Their services are provided through VSAT service providers. Intelsat is a wholesaler of satellite transponder capacity [10].

1.1.2.2.3. Inmarsat

Inmarsat is a network of ten geostationary satellites that provide high bandwidth communication for aeronautical, marine and other mobile applications. Only Inmarsat 4 satellite F-2 (53o W) and Inmarsat 3 satellite F-3 (181.8o W) are available for use in the United States. Current coverage in certain areas of California is marginal at best [11]. However, Inmarsat is planning to add a new satellite in 2008 that will cover the West Coast and, in particular, Northern California [12]. Inmarsat also provides wideband communication with a small mobile terminal that is roughly the size of a pizza box. The antenna is integrated into the router and does not require precision pointing. Inmarsat equipment, monthly subscription charges, per minute/MB usage fees, and activation fees are very expensive when compared other GEO services such as HughesNet. However, if Inmarsat is the only viable form of communication at a given location, the expense may be justified based on the need for information.

1.1.2.3. Satellite ISP

There are several satellite ISPs, most of which operate VSAT networks. Typical upload speeds are 128 to 256 kb/s and download speeds are 512 kb/s to 1.5 Mb/s. Dish antenna sizes are typically 3.2 to 3.9 feet in diameter, depending upon signal level requirements. Individual satellite ISPs WildBlue and HughesNet are discussed below.

Typical costs for services:

Monthly cost for 700 kb/s down/128 kb/s uplink is $59.99 [13]. Virtual Private Network (VPN) capability is also available from companies such as Ground Control [14]. A five node VPN lists at $619/month (Galileo plus 4 – 1544 Kbps Down/256 Kbps Up, 4 GB monthly transfer allowance, 1 year contract) [15]. Costs vary from system to system but are typically significantly less than those of a VSAT system.

1.1.2.3.1. WildBlue

WildBlue is a geostationary satellite-based ISP operating in the 20–30 GHz K_a band, which enables use of a 26-inch diameter satellite mini-dish [16]. The Anik F2 and Wildblue-1 satellites are above the Equator at 111.1° W longitude [17,18, 19]. The operating K_a band frequency is such that transmission can be affected significantly by rain or snow, so during rainfall or snowfall transmission can be interrupted. During a significant rainstorm it might be necessary to transmit warnings to a CMS, obtain critical weather information from an RWIS or cover an affected area with a CCTV for example [20]. Also because of the satellite location and the irregular terrain in some areas of California, there may be other serious questions as to WildBlue viability. Many field elements may be shielded by mountains or forestation, particularly since the wavelength of the K_a band frequencies is close to the length of redwood needles, causing them to absorb a significant amount of power. The problems associated with the K_a band (e.g., rain or snow corrupting the signal) probably call for careful consideration regarding the use of WildBlue for any field element site in certain geographic areas since TMS-TMC coverage during a rain or snow storm might be crucial. In the absence of other options, it might be decided that WildBlue is a viable option. Note that in areas in California with limited precipitation WildBlue would be more viable. WildBlue does not provide mobile service and is therefore not available for use as part of a PATIS unit at this time. Note that aligning the site antenna to the satellite may be complicated.

1.1.2.3.2. HughesNet (formerly DirecWay)

HughesNet provides an Internet service on a VSAT platform. Unlike WildBlue, which operates in the K_a band, HughesNet operates on the K_u band (that is not significantly corrupted by rain or snowfall) and offers service virtually everywhere in the United States. HughesNet uses seven satellites for Internet coverage of the lower 48 states [10]. The seven satellites are identified as Galaxy 26, AMC-9, Galaxy 28, Galaxy 16, Satmex 5, Galaxy 11, and Horizons 1. HughesNet does not use a spot beam technology which makes it highly portable and usable as long as the satellite footprint offers adequate signal strength. Aligning the dish to the satellite is non-trivial and may prove to be challenging and time consuming for the non-technical user.

Typical costs for services:

HughesNet offers five service plans as shown in Table 1 [13,21]:

Table 1: HughesNet Service Plans

Package	Data Rates	Monthly Cost
Home Service Plan	700 kb/s down/128 kb/s uplink	$59.99
Pro Service Plan	1Mb/s down/200 kb/s uplink	$69.99
Pro-Plus Service Plan	1.5 Mb/s down/200 kb/s uplink	$79.99
Small Office Service Plan	1.5 Mb/s down/300 kb/s uplink	$99.99
Business Internet Plan	2 Mb/s down/500 kb/s uplink	$179.99

Typical costs for equipment hardware:

The first three plans listed in Table 1 require a 2.4 foot dish, .74m antenna, 1W radio, and an HN700S modem at a cost of $399.98 for equipment and installation (with a two-year service plan). The Small Office and Business Internet plans require a 3.2 foot dish, .98m antenna, 2W radio, and an HN700S modem at a cost of $699.98 for equipment and installation (with a two-year service plan). A pole mount is included with the two commercial plans. Since the system uses multiple K_u band satellites, it has fewer weather or location limitations than WildBlue.

Note: *HughesNet has a "Fair Access Policy" based on a cumulative download threshold, which is determined by the service plan. When the threshold is exceeded, the data rate is reduced to 56–400 kb/s (depending on the service plan) until the user's system refreshes—typically within 12–24 hours [22]. However, CCTVs primarily require uplink communications and thus are not affected by the download constraint. HughesNet also has its own new K_a band satellite Spaceway 3 in orbit and is expected to place it in commercial operation soon [23].*

1.1.2.3.3. GEO Satellite Summary

Benefits associated with this technology:

K_u band satellites are not as significantly affected by weather (rain, snow, etc.) as are K_a band satellites.

Drawbacks associated with the use of this technology:

User costs are somewhat higher than other viable technologies when available. Monthly service charges apply and can be significant. Signal latency is roughly ¼ second for the signal to reach the satellite and return to a network node. Including delays within the network, total latency may reach more than 1.5 seconds. K_a band satellites such as WildBlue are more negatively impacted by weather such as rain and snow than are K_u band satellites such as HughesNet and Inmarsat. Aligning the satellite dish is non-trivial and may prove to be challenging, particularly for an inexperienced user, typically taking one to three hours. (For an experienced user the dish alignment would typically take 30 minutes to an hour.)

Range of use:

Essentially unlimited.

When/How this technology should be used:

Whenever a GEO satellite is accessible to a field element, it may be appropriate whenever other viable, and less expensive, options are not available. In some cases, it could be used for access to a roadside LAN that requires high data rates; otherwise it is most applicable for direct TMS to TMC communications given the acceptance of usability challenges such as positioning the dish antenna.

When/Why this technology would not be used:

When other less costly, viable options with adequate bandwidth are available or when line-of-sight to a GEO satellite is obstructed by terrain or vegetation. If signal latency (delay) is an issue, a GEO satellite would probably not be viable.

Installation/Maintenance issues/considerations:

Physical installation and maintenance of the equipment hardware (e.g., exchanging a device or positioning the satellite dish) can be performed by staff. Positioning of the dish antenna may be non-trivial and pose challenges particularly for a non-technical user. Care needs to be taken in selecting an installation site that ensures line-of-sight access to the satellite.

Summary:

HughesNet accessibility is limited only by view of the sky. Whenever the use of satellite communications is appropriate, this would be a viable choice. HughesNet was chosen as an example, among several GEO satellite systems, since its footprint essentially covers the entire State of California. HughesNet, as well as other satellite service providers, can provide a VPN that would allow simultaneous access to several PATIS sites. Note that some GEO satellite systems provide limited access to California and one, WildBlue, does not provide mobile service and operates in the K_a Band which is more susceptible to rain and snow interference. Again note that aligning the site antenna to the satellite is non-trivial and may be problematic. We note that Inmarsat currently provides inadequate coverage of California, but is launching a new satellite later in 2008 that will provide coverage in the Pacific Coast area. Inmarsat provides a mobile Internet Protocol (IP) based service, Broadband Global Area Network (BGAN), which would also be appropriate for work zone access when the new satellite is in place.

1.1.2.4. Low Earth Orbit (LEO) Satellite Systems

LEO satellites are placed at distances closer to the earth's surface and hence have significantly smaller footprints than a GEO. Antennas directed at LEO satellites must either track the satellite or be non-directive. LEO satellite systems have lower data transmission rates and are good for mobile applications particularly in locations where GEO is not available. LEO systems have substantial limitations relative to field elements, particularly in areas with irregular terrain or dense forestation. There are three systems in operation: Globalstar, Iridium and Orbcomm They have limited footprints that vary as the LEO satellites rotate in orbit and probably will limit the time of contact with the user units, particularly in irregular terrain. They operate in a frequency band (S-band – 2 to 4 GHz) such that the length of some conifer needles may be close to 1/4 wavelength of the operating frequencies and, thus, may absorb considerable RF energy. All LEOs have limited data rates and may experience periods of outages due to sky obstruction particularly in irregular terrain. However, LEO service is available whenever a view of the satellite footprint is available. In flat terrain (e.g., a large valley) this is almost always the case. The tradeoff may be viable if no other services are available at a particular location. All LEO systems are very portable and might be applicable to set up an initial response to a highway emergency such as a landslide.

1.1.2.4.1. Iridium

Iridium is a LEO satellite system with 66 satellites. The system offers a data communication rate of 2.4 kb/s uplink and downlink, which could possibly be used for low data rate Intelligent Transportation System (ITS) applications [24]. Note that the data rate is relatively low and might not be viable for access to some field elements. The data rate should be sufficient for communication with a CMS or other low data rate device.

1.1.2.4.2. Orbcomm

Orbcomm is a LEO satellite system comprised of 30 satellites. This system is specifically intended for machine-to-machine communication. The system allows short messages ranging between six bytes and several kilobytes to be sent and received in near real-time [25].

Equipment for Orbcomm's system can be as small as 2.5 inches wide x 2.5 inches long and an inch tall. The omni-directional antennas are also small and do not require pointing. Orbcomm equipment can be run off solar charged batteries. The system offers a data communication rate of 2.4 kb/s uplink and 4.8 kb/s downlink, which could possibly be used for low data rate ITS applications [26]. The 4.8 kb/s downlink rate meets the minimum requirements for a CMS.

1.1.2.4.3. Globalstar

Globalstar is a LEO satellite system with 40 satellites at a higher orbit than that of Iridium. Hence, the Globalstar footprint is larger than that of Iridium. In irregular (mountainous) terrain, however, both systems experience time gaps in coverage. Data systems tend to be small in size. The satellite radio is typically the size of a hardback book, and the antenna is the size of a doughnut. Data communications rates are 7.2 kb/s, which is insufficient for use for CCTV, but could be used for low data rate ITS applications [27]. Globalstar has lost eight of its 48 satellites in the past few years, but added 4 on May 29, 2007, and scheduled an additional four for launch on July 31, 2007. (As of this date no information is available on the Globalstar web site as to the July 31, 2007, launch.) Globalstar's problems are significant and have not been resolved as of this writing.

1.1.2.4.4. LEO Satellite Summary

Benefits associated with this technology:

LEO systems are very portable. LEO satellites are often accessible where landline and cellular are unavailable. Deployment can be relatively straightforward as it is not necessary to point the antenna since omni-directional antennas are used with these systems. In those cases where no other system access is available, LEO satellites will provide at least limited access.

Drawbacks associated with the use of this technology:

LEO systems typically suffer from low data rates, high costs, time gaps in accessibility and system problems. Iridium operates in the K_a Band, which further limits access during rainy or snowy weather. Monthly service charges apply. Irregular terrain and dense vegetation may negatively impact service. Lapses in coverage will occur when the mobile unit is outside of the current footprint of a LEO satellite.

Range of use:

Limited to times when a field element is in the satellite's footprint.

When/How this technology should be used:

If no other viable option is available.

When/Why this technology would not be used:

Cost of use is very high relative to data rate. Access to satellite footprint may be very limited in irregular terrain.

Installation/Maintenance issues/considerations:

Self installed. User must be careful to place modem system in the most accessible location (at a field element site) within the satellite footprint. Physical maintenance of the equipment hardware (e.g., exchanging a device) can be performed by staff. Technical support would be provided by the service provider.

Typical costs for equipment hardware:

- Iridium Beam RST voice/data module: $2,305 [28].
- GSP-1620 Globalstar Duplex Satellite Modem: $995 [29].
- Orbcomm: details unavailable.

Typical costs for services:

- Globalstar: Unlimited use currently $39.99/month subject to reduction to $19.99 in 2009 [30].
- Iridium: Two monthly rates with included minutes: 20 min/month, $68.95; 60 min/month, $100.95 plus prepaid airtime plans [31].
- Orbcomm – details unavailable.

Summary:

Because of relatively high usage costs, limited access to the satellite footprint and system problems (e.g., "burned out" satellites) this would not be an option of choice except in circumstances where no other option was available.

1.2. HAR Licensing Considerations

HAR licenses are not fixed site but regional in nature, e.g., city, county or statewide. This, of course, is essential for a portable system. HARs typically have a coverage area of a 3-5 mile radius from the antenna. Range, of course, is limited by the sensitivity of the AM or FM receiver in a vehicle. Federal Communications Commission (FCC) waivers can be obtained for "superstations" with high gain antennas extending the range to 10-15 miles, although the antenna is not "portable". Licensing procedures for HARs and on-site training services are available from the manufacturers. Note that the FCC refers to HARs as Traveler information Stations (TIS).

We note that there are limitations to the use of HARs. In particular, licensing of HAR is restricted to government agencies. Additional FCC licensing information is available on the FCC web pages (See Appendix A). Hence HARs must be operated by Caltrans. This may not be a significant restriction for general road construction, however, since portable CMSs can be placed at critical locations to provide essential traveler information although not in as much detail.

1.3. Intra-Work Zone Communication

For local communications between a traffic sensor and a CMS and/or controller, for example, there are numerous options:

- In more remote areas where interference is unlikely, unlicensed systems such as a 900 MHz Industrial, Scientific, Medical (ISM) band LAN, Wireless Fidelity (WiFi) or Worldwide Interoperability for Microwave Access (WiMAX) could be used to communicate among units closely located within a work zone. WiFi and WiMAX operate at high frequencies and low power, however, such that a LAN might require multiple elements.

- In rural areas where unlicensed frequencies may not be appropriate, radio frequency (RF) modems, particularly in the VHF high band, may provide good intra-zone communications. Note, however, that VHF high band typically is limited to 9.6 kb/s, which may be inadequate for some applications such as CCTV cameras for viewing traffic. Higher RF frequencies (e.g., 700 and 900 MHz) with higher data rate capabilities may also be used. However, in mountainous and/or heavily forested areas (referred to as "irregular terrain"), which are common in California, RF propagation may be affected, particularly in the higher frequency bands. In such cases it may be necessary to place one or more portable repeaters between the endpoints of the work zone. It is here where VHF high band, whenever 9.6 kb/s is adequate, will provide the best propagation coverage. For example, in a five mile construction zone in very irregular terrain, VHF high band would typically require one or two repeaters whereas the higher bands might require as many as four or five.
- In more urban areas, where interference to unlicensed frequencies would be more likely, RF modems in the 150 - 900 MHz licensed frequency bands could be used for intra-site communications. If higher data rates (greater than 9.6 kb/s for VHF or UHF and 19.2 kb/s for 800 MHz) were required, the 700 (384 kb/s) or 900 (768 kb/s) MHz bands might be required.

We do need to note that equipment vendors are continually improving data rates in RF modems, typically at the expense of receiver sensitivity, however, with more advanced modulation schemes or higher RF bandwidth. Currently at least one vendor, for example, lists a VHF high band RF modem with 19.2 kb/s digital bandwidth, but requiring 25 kHz RF bandwidth. Since FCC "Refarming", which reduces bandwidth limits by a factor of two, will occur on January 1, 2013, this would not be a viable long term option.

1.4. HAR Equipment

One HAR equipment provider, ISS, for example, manufactures a ruggedized portable system that is easily transported and can be set up or taken down (for overnight storage, for example) in a matter of minutes [32]. They also manufacture a solar-powered, trailer-mounted portable HAR system.

Figure 2: ISS Portable HAR System – Image Courtesy of RadioSTAT and The Radio Source

Quixote Transportation Technologies offers two portable solutions. Solar Max is a portable, solar-powered HAR system (see Figure 3). Alert Max is a portable, solar-powered CMS/HAR system (see Figure 4) [33].

Figure 3: Solar Max System – Image Courtesy of Quixote Transportation Technologies

Figure 4: Alert Max System – Image Courtesy of Quixote Technologies

Both vendors also manufacture solar powered, stand-alone, portable CMS systems. Quixote systems are designed for cellular message changes. ISS systems are designed for telephone or computer IP-based controlled message changes. Another manufacturer, ADDCO, markets a line of trailer mounted CMS, either solar or battery powered, that are message controlled either by a handheld terminal or a cellular modem. Two that seem most appropriate for this discussion are the Mid-Size Full Matrix unit and the Mini Adjustable Graphic (MAG) Sign, as seen in Figure 5 and Figure 6 [34].

Figure 5: ADDCO Mid-Size Full Matrix Portable CMS Unit – Image Courtesy of ADDCO

Figure 6: ADDCO MAG Sign Portable CMS Unit – Image Courtesy of ADDCO

Security may be an issue with portable HAR units, particularly regarding theft or vandalizing. Hence, it may be advisable to consider system protection (e.g., portable fencing system with an intrusion alarm). The placement of a portable HAR and/or portable CMS along a highway requires that they can be protected from either intentional or accidental damage.

2. MULTI-DAY INCIDENT CASE STUDY

Portable Advanced Traveler Information Systems (PATIS) involve several options including ATIS systems operated by Caltrans, by contractors or by a Caltrans-contractor team. Typically they may involve;

- Fixed or portable CMS and/or portable HARs to inform travelers of road construction or emergency highway conditions (noting that HARs may only be operated by governmental agencies – see Section 1.2),
- Communication links from a TMC or local control point to the CMSs and/or HARs to keep traveler messages up to date,
- Local area communication networks to advise travelers, via a portable CMS, of traffic delays (e.g., approximate arrival time of a pilot car).

An example of how these various options might be implemented involves a landslide on California SR 96 in Humboldt County which is discussed in Section 2.2.

2.1. Background Information - State Route (SR) 96, California

SR 96, also known as the Bigfoot Scenic Byway, is a 147 mile [35] rural, two-lane, mountainous roadway that follows the Trinity and Klamath Rivers in northwestern California through the Marble Mountain Wilderness [36]. SR 96 originates in Willow Creek (Junction 299), and terminates on the outskirts of Hornbrook where it merges with Interstate 5 (I-5). There is a junction with SR 169 at Weitchpec. Figure 7 shows a map of SR 96.

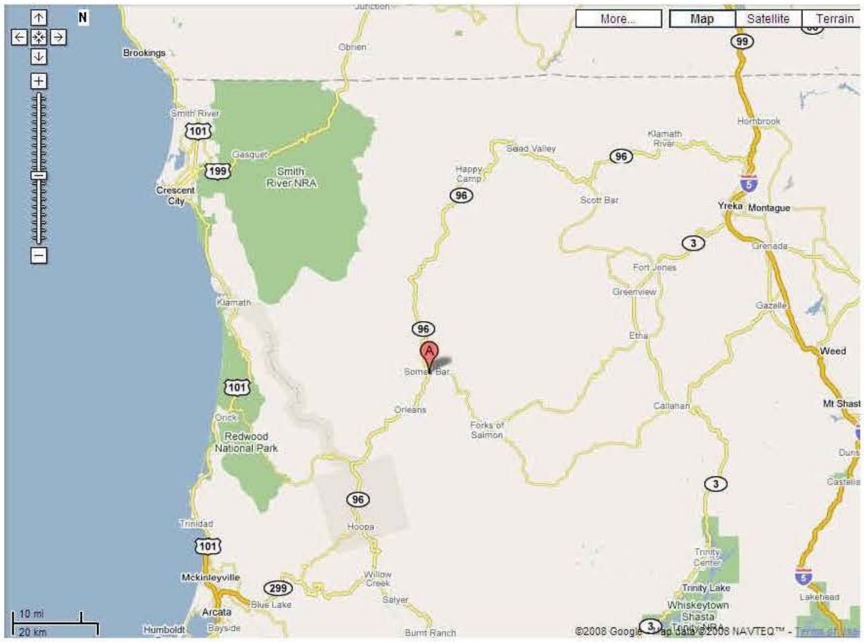


Figure 7: Map of SR 96 - Courtesy of Google Maps

The SR 96 roadway traverses Humboldt and Siskiyou counties. It services several recreational areas in the Klamath National Forest. SR 96 is the primary entry/egress route for the recreational areas and several towns. In 1992, the average daily traffic volume ranged between 500 and 3,800 vehicles per day [36]. Given the geographic features of the area through which the roadway passes, landslides in the rainy season and summer wildfires are not uncommon. Fires, landslides, or other major incidents can severely impact visitors and local area residents. Alternate routes are not readily available. Reliable communications, timely response, accurate traveler information and traffic control are essential components needed to address public safety in such a situation. PATIS systems would play a key role in any emergency situation such as a fire evacuation on SR 96.

2.2. SR 96 Post Marker (PM) 17 Incident

The following information was supplied by Caltrans District 1. In the early morning hours of December 20th, 2007, a major landslide occurred on SR 96 post marker 17 approximately 3 miles north of the town of Hoopa, California in Humboldt County at latitude 41°07'11.27'N and longitude 123 °41".20.12'W. Figure 10 shows the approximate location of the landslide.

Figure 8: SR 96 Landslide Location - Image Courtesy of Google Earth

Caltrans estimates that 1200 cubic yards of rock and debris fell, damaging and blocking the roadway in both directions (see Figure 9 and Figure 10).

Figure 9: Landslide on SR 96 – Image Courtesy of Caltrans District 1

Figure 10: Landslide on SR 96 – Image Courtesy of Caltrans District 1

Incident Response

Caltrans responded to the incident by sending maintenance crews to the site. An initial assessment of the incident determined that they did not have the resources available (i.e., manpower and equipment) to address the work load. Crews immediately contacted Caltrans Headquarters in Sacramento via cell phone and initiated a verbal contract for a Force Account Project (FAP) to clear the debris and re-open the roadway. As debris was removed, it became apparent that a portion of the westbound lane had been lost. Consequently, the roadway was re-opened to a single lane of traffic three days after the slide occurred. Coordination with the local power company was required as power lines were downed in the landslide.

The Public Information Officer (PIO) notified the media and public of the immediate road closure. When the roadway was re-opened to a single lane of traffic, flaggers were used around the clock to direct traffic until a temporary traffic signal system could be installed. Roadway reconstruction and slope and drainage repair is scheduled for completion in November 2010 and is being funded by the State Highway Operation and Protection Program (SHOPP) [37].

2.2.1. Communications Options

In a situation such as this landslide, data communication to/from the TMC is essential in order to re-route traffic, insure appropriate response by construction crews and, as the highway is cleared of debris, to establish a viable traffic control system. When possible and/or permitted, such a link might be established by an RF system operating from State Public Safety microwave or 800 MHz towers. Other RF links may be required along the work zone, to CMSs and or HARs, to/from traffic monitoring devices, etc. For this reason we have used ComStudy2.2, an RF propagation coverage program, to illustrate where communication links might be established from a specific site. For all propagation studies included in this document, red indicates excellent coverage, yellow indicates very good coverage, green indicates acceptable coverage and white indicates no coverage from the site under consideration. If another location is in a colored area this indicates that a communication link is available to/from that site.

Figure 11 is an example of the level of RF coverage of the landslide site from the nearest State tower operating in the 700 MHz band (which has significantly higher digital bandwidth capabilities than VHF or Ultra High Frequency (UHF) frequencies). Figure 12 is a sample coverage plot from the same State tower in VHF high band (~151 MHz) to demonstrate the difference in levels of coverage among different frequency bands. Neither plot indicates coverage of the landslide. If in general however, a Caltrans base station at a State microwave or 800 MHz tower were located such that there was suitable coverage of a work site this would be a good communications option to consider for communication to/from the TMC.

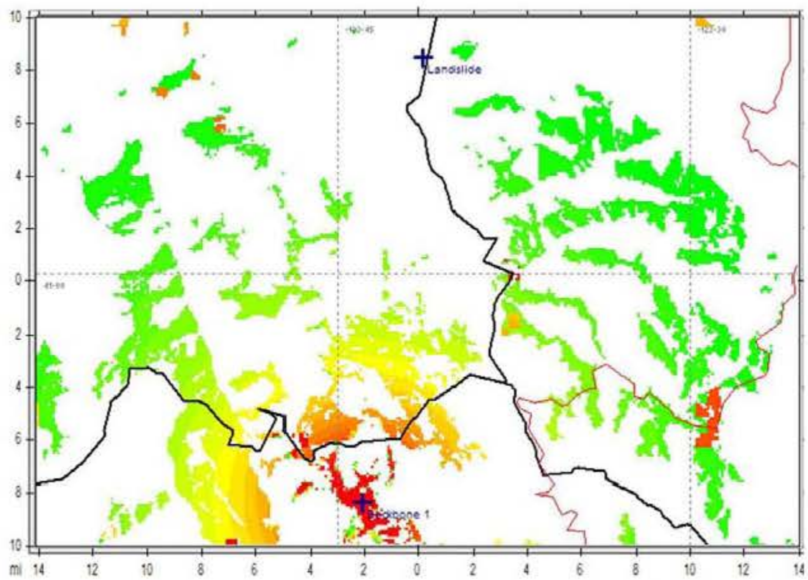


Figure 11: RF Coverage Plot from the nearest State Tower Operating in the 700 MHz Band

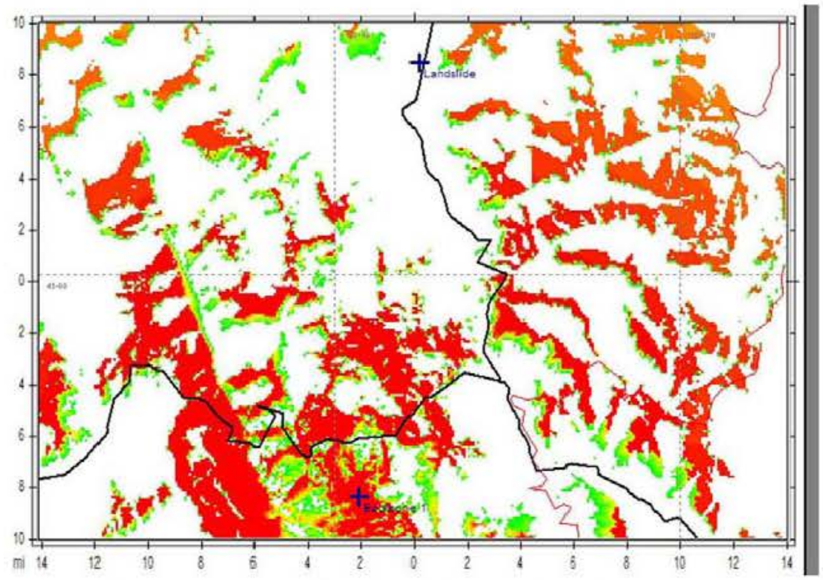


Figure 12: RF Coverage Plot from the Nearest State Tower in VHF High Band

One alternative to a standard RF link between the landslide construction zone and the TMC would be a cellular link. Figure 13 indicates that cellular coverage from a Verizon cell site would be very good at several locations close to the landslide. Although coverage at the landslide is questionable, a control site with good coverage could be located close to the landslide. In general, cellular communication from the TMC to/from the work site may be a good option in many cases where cellular providers have adequate coverage along highways where coverage by a Caltrans RF system does not exist. When good cellular coverage is available it may be the least expensive option.

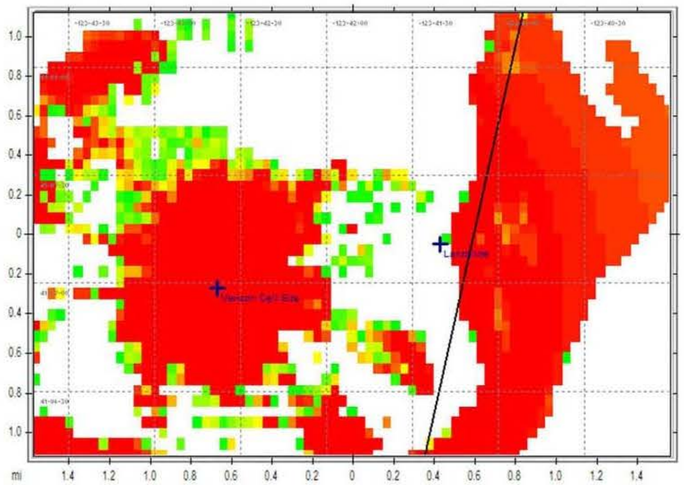


Figure 13: Verizon Cellular Coverage Plot

Figure 14 is an augmented display of the ComStudy propagation plot overlaid onto a Google Earth map. Based on the figure, it is not clear whether or not coverage is available at the landslide location, although it is available at sites near the landslide. Measurements would need to be taken at the site to determine the availability and quality of cellular coverage at the landslide location.

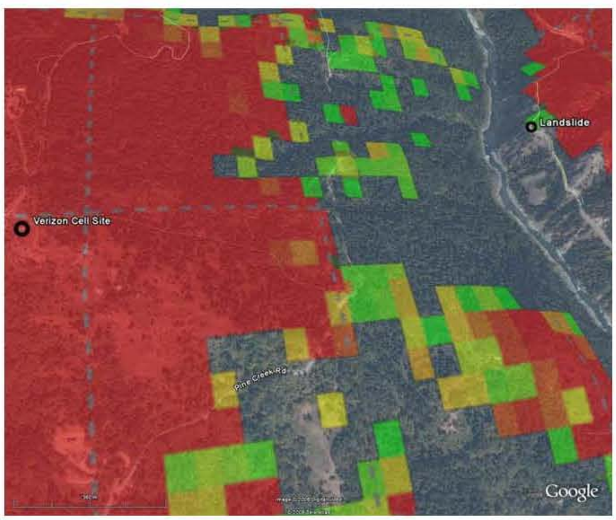


Figure 14: Augmented Coverage Display

The cell site is approximately 1.7 km (slightly over one mile) from the landslide and the nearest red zone on the highway (excellent coverage area) is less than 150 meters from the landslide.

A portable relay LAN could be appropriate in many construction zones. It would consist of a sequence of RF modems along the construction route. It can provide a communication link to change messages on CMSs or HARs at either end of the construction zone. For example, it could provide information to travelers waiting for a pilot car on its approximate arrival time. Such a LAN requires that successive roadside modem locations have a good RF coverage path to the nearest modem location(s). Figure 15 is the RF coverage plot of a VHF high band portable relay LAN site at, or very near to, the landslide. Figure 16 and Figure 17 are coverage plots from portable relay sites at locations at both ends of a possible construction zone. These relay LAN sites would provide communication between both ends of the construction zone, at a 9.6 kb/s data rate, and, for example, a site at which a cellular modem could be connected to the relay system for TMC control of or to receive information from CMSs or HAR messages at the construction zone. We have assumed for this example that such a "control site" would be near the landslide.

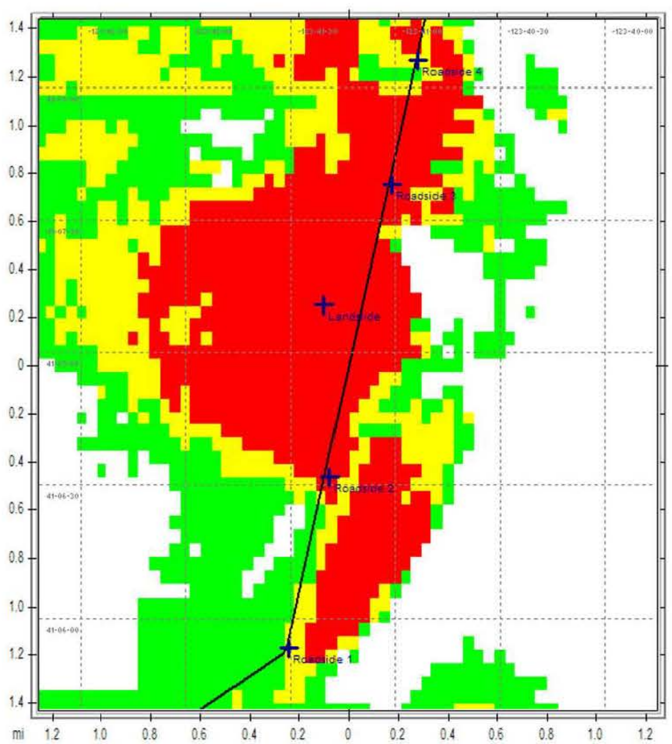


Figure 15: RF Coverage Plot of a VHF High Band Portable Relay LAN Site at the Landslide Location

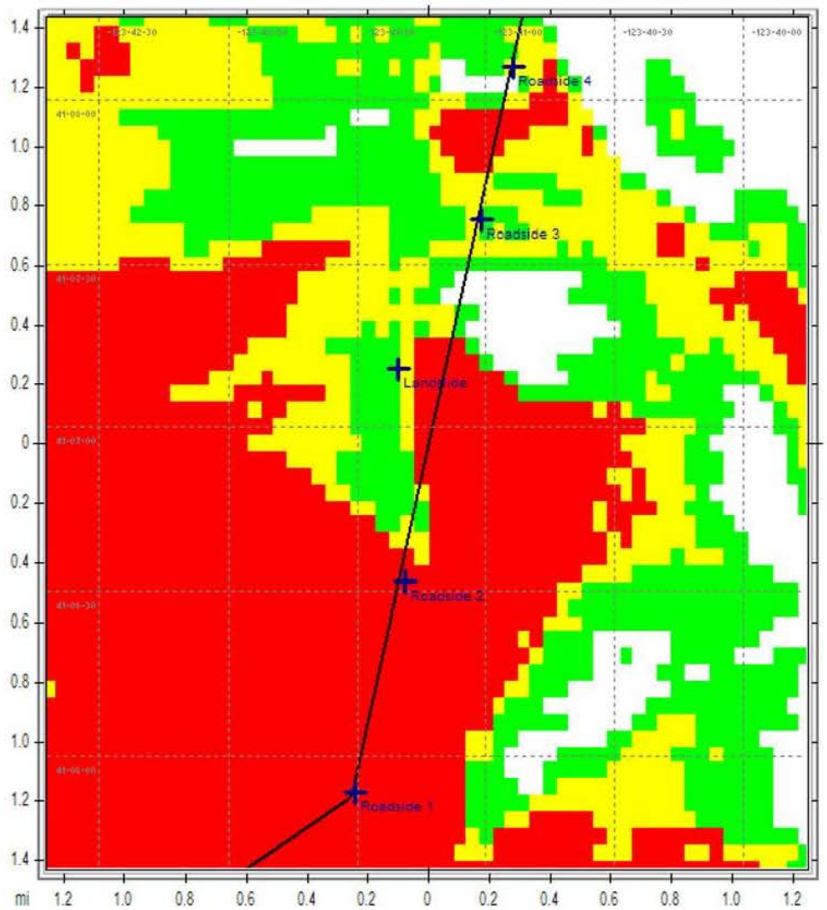


Figure 16: Coverage Plot from Portable Relay Site Roadside 1 at One End of the Possible Work Zone

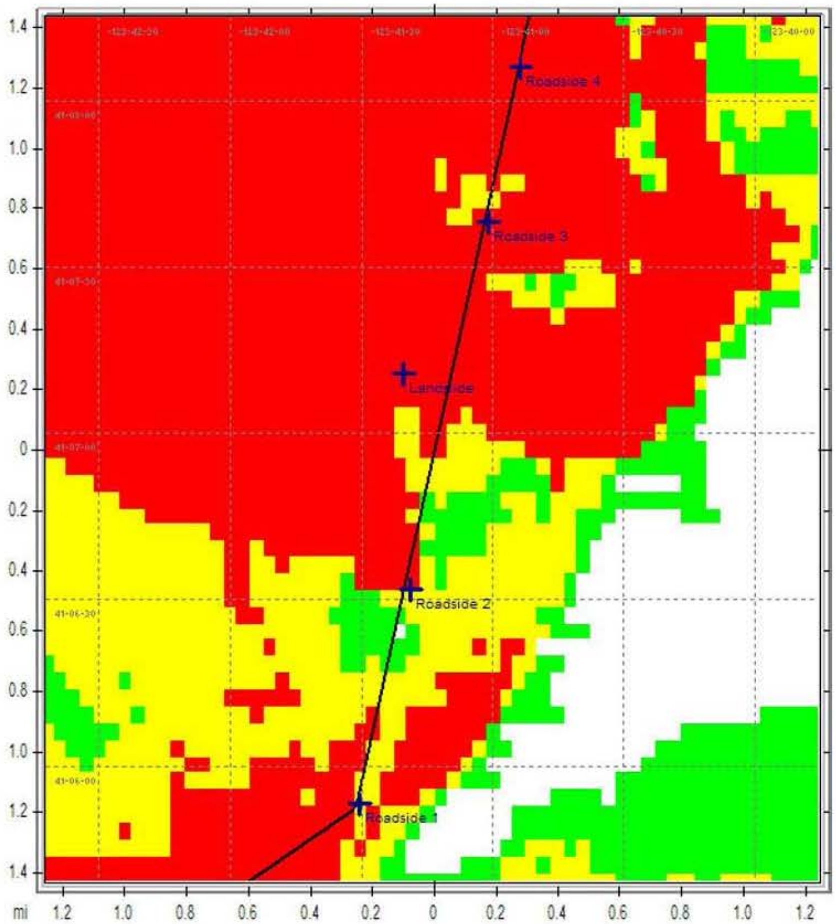
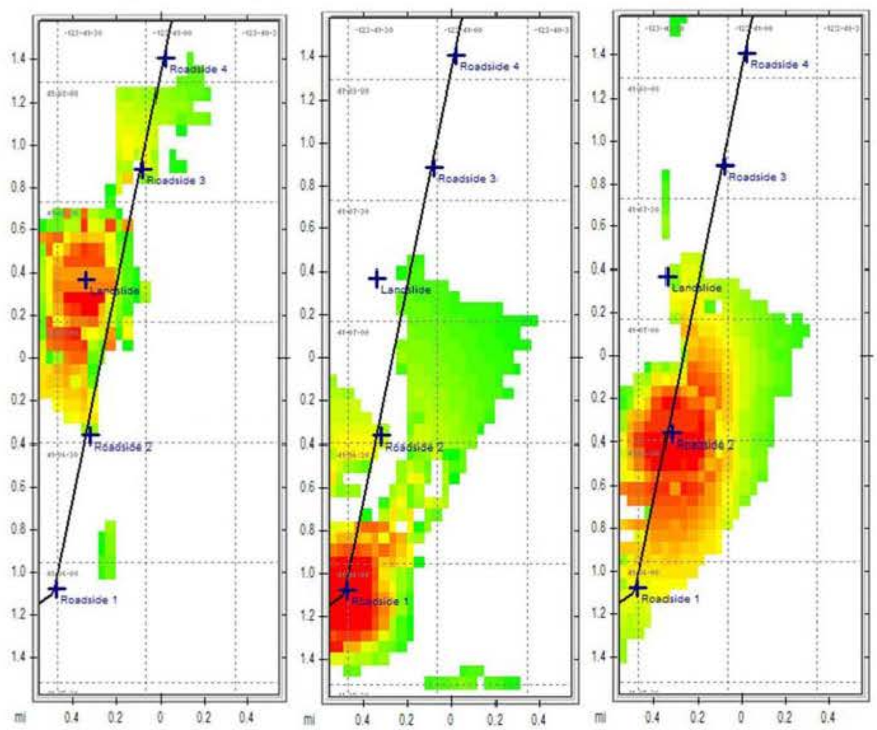


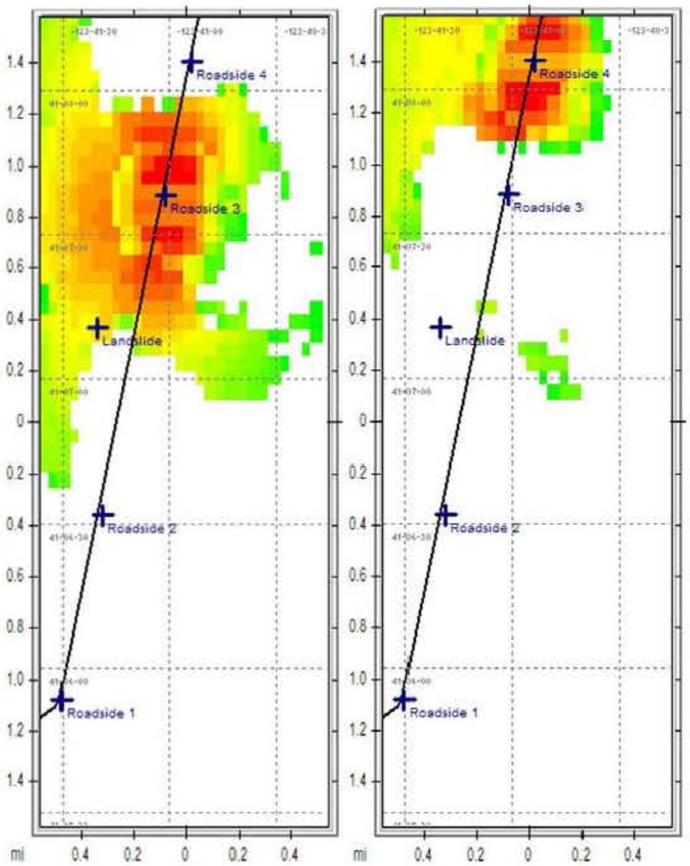
Figure 17: Coverage Plot from Portable Relay Site Roadside 4 at One End of the Possible Work Zone

In this particular case we note that a VHF relay through the control site near the landslide would not be required for point-to-point contact between work zone endpoints to predict arrival times of a pilot vehicle but would be required for the control site to change CMS or HAR messages. A 900 MHz relay LAN with units at all five sites, although not providing as much coverage, would also be viable, using, for example, a GE MDS 900 Mercury system with a data rate of 250 kb/s. The MDS 900 Mercury uses the unlicensed ISM Band, 902-928 MHz. Although unlicensed frequencies may experience interference, significant interference would be unlikely in a construction zone. See Figure 18 and Figure 19. Note that coverage of "Roadside" sites is only required between two successive sites for a repeater relay. Figure 18 and Figure 19 illustrate bi-directional point-to-point coverage to/from the nearest Roadside site. For example, Figure 18A shows coverage between the Landslide control site and Roadside sites 2 and 3. Figure 18B shows coverage between Roadside sites 1 and 2, Figure 18C shows coverage between Roadside site 2 and the Landslide control site, Figure 19A shows coverage between Roadside site 3 and the Landslide control site and Figure 19E shows coverage between Roadside sites 3 and 4. Recall that red indicates excellent RF coverage, yellow indicates very good coverage and green indicates acceptable coverage.



A) Landslide Coverage B) Roadside 1 Coverage C) Roadside 2 Coverage

Figure 18: 900 MHz Coverage Plots for Relay LAN Sites in Landslide Work Zone



A) Roadside 3 Coverage B) Roadside 4 Coverage

Figure 19: 900 MHz Coverage Plots for Relay LAN Sites in Landslide Work Zone - Continued

GEO satellite "line-of-sight" access to the landslide site is illustrated in Figure 20 for HughesNet (viewed from the North). As seen in Figure 20, there is excellent line-of-sight (the red lines between the site and the satellites) to the HughesNet satellites from the landslide location. Note however, that because of the complexity of antenna alignment to a satellite, or the cost of a self-aligning dish antenna, at work zone entry points use of GEO satellites for communication to CMSs or HARs may not be appropriate. Since communication to a CMS or HAR does not require a significant data rate, a LEO satellite may be appropriate, particularly in open terrain where the LEO footprint is not significantly affected by terrain. It remains up to Caltrans to determine the need for information from any remote location and/or the need to relay information to a location. The need for information to/from a site will drive the selection of the communication technology.

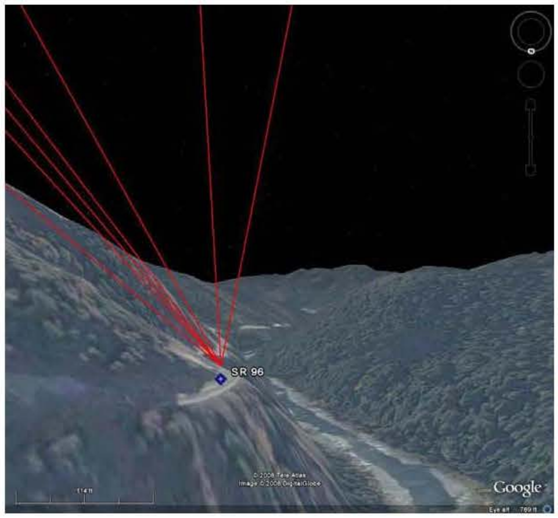


Figure 20: Lines-of-Sight to HughesNet Satellites - Image Created Using Google Earth

There are also other TMC to construction zone communication options. When available (although an unlikely option at most construction zones) POTS connections could provide adequate digital bandwidth for data communication to a TMC or along a construction zone. A more appropriate option, and one that would apply to the present example, would be GEO satellite communication. The HughesNet satellite system, for example, has numerous satellites that provide coverage virtually over the entire State of California. Note, however, that if the path (from the user dish antenna to the satellite) at an angle of 40° or less from vertical to the satellite is obstructed by terrain or vegetation HughesNet will not have a line-of-sight. In this case only a LEO satellite may have intermittent access to the construction zone if no other RF connections exist. Hence, if cellular, Plain Old Telephone Service (POTS) or RF systems did not provide suitable site coverage in a construction zone, this would probably be a viable option. In those cases where only cellular or GEO options were available, either for connection to a TMC or for communication in a construction zone in very irregular terrain, the cost comparison of the two services would probably be a deciding factor in selection of the option. Typical costs of Verizon digital cellular [3] and HughesNet GEO satellite services [21] (for Verizon and HughesNet) are listed in Table 2.

Table 2: Cellular and Satellite Services Pricing Information

Provider	Access	Connection Type	Speed	Availability	Cost
Verizon	Unlimited	Cellular 1xRTT	144 kb/s uplink and downlink	Currently available	$59.99/month
Verizon	Unlimited	Cellular EVDO	2.4 Mb/s uplink and downlink	Late 2008	$59.99/month
HughesNet	Unlimited	Satellite	128 kb/s uplink 700 kb/s downlink	Currently available	$59.99/month

We note that either Caltrans or a contractor could obtain these services and use them at any construction site in the State, i.e. they are totally "portable".

2.2.2. Highway Advisory Radios

HARs near the construction zone can provide an excellent information source for travelers. Normally they would be placed several miles on either side of the construction zone to allow travelers to be aware of the type of construction (e.g., routine highway construction or maintenance, emergency conditions such as a landslide, etc.) or to allow them to choose an alternate route. For this example two HARs, placed north and south of the landslide site might appear as in Figure 21. HARs must be controlled from a TMC since they can be licensed only by a governmental agency. This might be done by cellular or satellite link, for example.

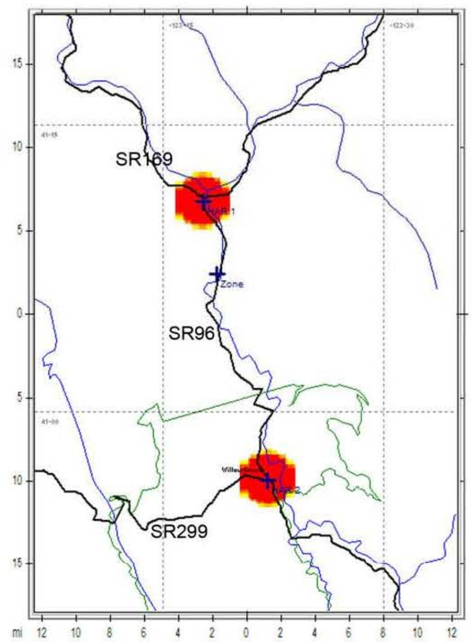


Figure 21: Prospective HAR Site Coverage Plot near Landslide Location

Placement of the HAR sites for an incident such as this landslide would normally be at the intersections of SR96 and SR169, and SR299 to allow traveler advisory of delays, road closure, alternate routes, etc. Note that portable HARs often have a portable CMS at the same site, typically to advise travelers to tune to the HAR.

2.2.3. Future Option

Currently under development is the Dedicated Short Range Communications (DSRC) system, which will provide data communications between a vehicle and a roadside site. It is a low power system intended for safety messages, emergency services and Internet access. Until such time as a majority of traveler vehicles are equipped to utilize DSRC (e.g., with a laptop computer or PDA), however, it will be of very limited use.

3. CONCLUSIONS

There are numerous communications options that may be applicable to support a PATIS unit. Following is a review of these options broken down into types of communication with the options listed:

- Communication to/from a Traffic Management Center
  - To a work zone control site
    - Where available, an RF link in any frequency band for voice communication or low rate data transmission
    - Where available, a cellular link for voice communication or low rate data transmission
    - A LEO satellite link for voice communication or low rate data transmission
    - Where available, an RF link in the 700MHz band for high data rate (384 kb/s) transmission
    - Where available, a wideband cellular link (e.g., 1xRTT, EV-DO, GPRS or EDGE) ,
    - Where available, a GEO satellite link
  - To a CMS and/or HAR
    - Where available an RF link in any frequency band for voice communication or low rate data transmission
    - Where available a cellular link for voice communication or low rate data transmission
    - A LEO satellite link, except, perhaps in irregular terrain that would cause significant delays between transmissions
    - Where available a GEO satellite link
- Communication from a work zone control site
  - To a CMS and/or HAR or to a flag site in order of preference
    - An RF repeater relay in whatever frequency band is available/appropriate
    - Where available a cellular link for voice communication or low rate data transmission
- Communication to/form a TMC or work zone control site to a high data rate field element (e.g., vehicle detection system, CCTV)
  - An RF repeater relay in a high bandwidth frequency band (e.g., 700 or 900 MHz)
  - Where available a wideband cellular link (e.g., 1xRTT, EV-DO, GPRS or EDGE)
  - Where available a GEO satellite link
- Communication to/form a TMC or work zone control site to a remote CMS and/or HAR (to give travelers detailed delay or closure information)
  - Where available a cellular link for voice communication or low rate data transmission
  - A LEO satellite link
  - Where available a GEO satellite link

The above list is intended as a "User's Guide" to determine the most appropriate communication option for each application and includes consideration of applicability to the intended use, reliability and cost.

This document is intended to assist California Department of Transportation (Caltrans) staff in the analysis of prospective communications systems and technologies to connect remote/rural sites to a TMC in a portable application.

There are benefits and drawbacks associated with each technology discussed in this document. No one technology will satisfy all requirements. It remains up to Caltrans to determine the need for the ability to establish communication at any particular location. This need will assist in the determination of the most appropriate technology to employ. There is no single technology that will satisfy all communication requirements at any location.

Information presented in this document is not intended to replace sound engineering judgment and proper design performed by a qualified radio systems engineer.

4. APPENDIX A

AM HAR Information

FCC regulations for AM HARs (TISs) is covered in Rule 47CFR90.242. "Travelers' Information Stations operate in the AM Broadcast Band (530 kHz - 1700 kHz) and are limited to a 10 watt transmitter output power and the antenna height may not exceed 15 meters (49.2 feet). These stations may not transmit commercial information. This service is not available to individuals or groups, but only to governmental entities and park districts." [38]

Additional information is available on the FCC's Travelers' Information Stations Search web page - http://www.fcc.gov/mb/audio/bickel/tis.html.

FM HAR Information

FCC regulations for FM HARs (TISs) is covered in Rule 47CFR90.242. "…the Low Power FM (LPFM) radio service, which was created by the Commission in January 2000. These stations are authorized for noncommercial educational broadcasting only (no commercial operation) and operate with an effective radiated power (ERP) of 100 watts (0.1 kilowatts) or less, with maximum facilities of 100 watts ERP at 30 meters (100 feet) antenna height above average terrain (HAAT). The approximate service range of a 100 watt LPFM station is 5.6 kilometers (3.5 miles radius). LPFM stations are not protected from interference that may be received from other classes of FM stations. A construction permit is required before a LPFM station can be constructed or operated.

LPFM stations are available to noncommercial educational entities and public safety and transportation organizations, but are not available to individuals or for commercial operations. Current broadcast licensees with interests in other media (broadcast or newspapers) are not eligible to obtain LPFM stations.

LPFM stations must protect authorized radio broadcast stations on the same channel or frequency (co-channel), as well as broadcast stations on first, second, or third-adjacent channels above or below the LPFM station's frequency. This protection is accomplished through the use of minimum distance separation requirements, which are set forth in the FCC document 47 CFR 73.807 [PDF].

See http://www.fcc.gov/mb/audio/lpfm/index.html for additional information.

5. REFERENCES

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