California and Oregon Advanced Transportation Systems (COATS) Phase 4: Final Report

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EXECUTIVE SUMMARY

This document summarizes the work completed for continued Intelligent Transportation Systems (ITS) demonstration, evaluation and technology transfer in rural northern California and southern Oregon. This work was completed under the fourth phase (Phase 4) of the California and Oregon Advanced Transportation Systems (COATS) project. The purpose of the overall COATS effort has been and continues to be encouraging regional, public and private sector cooperation between California and Oregon organizations to better facilitate the planning and implementation of ITS in a rural bi-state area extending between Eugene, Oregon and Redding, California. As COATS has matured, it, as well as projects which have spun off from the effort, have gained interest from surrounding states, specifically Washington and Nevada. Consequently, the COATS region has evolved during the course of Phase 4 into the Western States Rural Transportation Consortium (WSRTC), which includes California, Oregon, Washington and Nevada. Although future research efforts will be conducted under the umbrella of the WSRTC, the work discussed in this document was conducted under the COATS umbrella and is discussed as such.

COATS Phase 4 activities included the Western States Forum and other general technology transfer activities, Deployment Assistance, Development of Radar Speed Sign Warrants and the Evaluation of the Fredonyer Pass Icy Curve Warning System. The Western States Forum served as a technology transfer platform where informative, in-depth technical presentations could be given by rural ITS practitioners. Presenters delved into how solutions were developed, focusing on applications that have been deployed in the field and are being used in live traffic situations. Success stories have been shared along with failures and problems so participants could learn what does and doesn’t work and why. The Forum has included live demonstrations of rural ITS technologies and “hands-on” question and answer periods. Participants have brought actual ITS equipment and performed informal “show and tell” sessions during the breaks.

Deployment assistance examined how to transfer web-based research products that are running in a laboratory environment to a production environment. The work completed during this task resulted in a number of recommendations. Prior to proceeding with external hosting, it was recommended that the general and specific changes documented be further addressed and implemented to optimize the system. Specific recommendations such as implementing server-side compression on text files served by the web server would immediately improve performance for users. Other items such as whether or not to archive data must be further discussed to weigh the advantages in terms of system performance and scalability with the disadvantages of reduced functionality. Code-refactoring should be implemented as time and funding allow. Finally, greater effort and emphasis needs to be placed on system documentation and on-going support and maintenance needs.

Development of guidance provided warrants for the acquisition and deployment of radar speed signs in a variety of settings to address speeding issues. Two levels of guidance were developed through this task: general guidance and location-specific guidance. General guidance warrants applied to cases where a radar speed sign may be used to address excessive mean speed and 85th percentile speed issues, ADT levels, speed limit compliance issues, accident history, pedestrian presence, and existing posted speed limits. Location-specific guidance applied to the use of radar speed signs in school and park zones, work zones, and general street locations such as transition zones, curve warning sign locations, and signal approaches. In addition to developing warrants for the use of radar speed trailers, specifications were developed for such equipment to guide practitioners in future purchases and deployments. The specifications developed related to the physical and functional specifications for both permanent post-mounted radar speed signs (and portable post-mounted signs) as well as trailer-based radar speed signs.

Evaluation of the existing Fredonyer Pass Icy Curve Warning system examined the safety and speed impacts as well as maintenance aspects of this particular deployment. Based on the results of this work, two conclusions have been drawn. First, the statistical analysis of speed data suggested that the system is working as intended and that vehicle speeds are significantly lower. This was particularly true of speed during clear, cold and dry weather conditions, when a driver would not necessarily expect to encounter ice. Second, the evaluation of crash data before and after system deployment found that the ICWS reduced the number of annual crashes by 18%. Additionally, investigation of crash rates indicated that the ICWS provided safety benefits of $1.7 million dollars per winter season during the “after” deployment study period.

1. INTRODUCTION

The purpose of this document is to summarize the work completed for continued Intelligent Transportation Systems (ITS) demonstration, evaluation and technology transfer in rural northern California and southern Oregon. This work was completed under the fourth phase (Phase 4) of the California and Oregon Advanced Transportation Systems (COATS) project. The purpose of the overall COATS effort has been and continues to be encouraging regional, public and private sector cooperation between California and Oregon organizations to better facilitate the planning and implementation of ITS in a rural bi-state area extending between Eugene, Oregon and Redding, California.

As COATS has matured, it, as well as projects which have spun off from the effort (One Stop Shop (OSS), Integration of Aviation Automated Weather Observing System (AWOS) with Road Weather Information System (RWIS), Redding Responder, WeatherShare, Automated Safety Warning Controller (ASWC), etc.), have gained interest from surrounding states, specifically Washington and Nevada. Consequently, the COATS region has evolved during the course of Phase 4 into the Western States Rural Transportation Consortium (WSRTC), which includes California, Oregon, Washington and Nevada. The WSRTC has been established to facilitate and enhance safe, seamless travel throughout the western United States. The Consortium seeks to promote innovative partnerships, technologies and educational opportunities to meet these objectives. Additionally, the Consortium seeks to provide a collaborative mechanism to leverage research activities in a coordinated manner to respond to rural transportation issues among western states related to technology, operations and safety. Consequently, activities of the Consortium are focused on technology transfer/education (Western States Rural Transportation Technology Implementers Forum) and incubator projects (small scale research projects intended to serve as a "proof of concept" for larger subsequent efforts) centered on the Consortium pillars of technology, operations and safety. Although future research efforts will be conducted under the umbrella of the WSRTC, the work discussed in this document was conducted under the COATS umbrella and will be discussed as such.

1.1. COATS Vision

The COATS Project is a cooperative bi-state, multi-modal project involving public-public and public-private partnerships that will develop, deploy and coordinate cost effective and reliable Intelligent Transportation Systems throughout state and local organizations. It is designed to increase safety, improve efficiency for the movement of people and goods, and increase the convenience and accessibility of real-time information and services, to a variety of surface transportation users on primary and secondary roadways within the project limits.

As part of the shift from COATS to the WSRTC, the vision of this effort has changed. The new vision for the Consortium is presented as follows. "The WSRTC shall promote innovative partnerships, technologies and educational opportunities to facilitate and enhance safe, seamless rural travel throughout the western United States." Following the conclusion of COATS Phase 4, the WSRTC vision shall be employed in future phases.

1.2. COATS Mission

The COATS Project will serve to focus member agencies on a seamless, state-of-the art, multi-modal transportation network benefiting travelers, goods movement, economic activity, and transportation systems operators in California and Oregon. Collaboration between the COATS project and its partnership coalition will provide information regarding the development of an effective ITS initiative which best addresses and improves the rural transportation needs of the region. Information gained will serve to promote increased safety, mobility, traveler comfort, environmental quality, and operational efficiency and productivity. Development of a fully functional and compatible ITS program will support long-term public/private partnerships, assist in the transfer of technology between public agencies and increase awareness of ITS technology among state and local officials, transportation professionals and transportation users.

Again, as part of the shift from COATS to the WSRTC, the mission of this effort has changed. The new mission for the Consortium is presented as follows. “The WSRTC shall provide a collaborative mechanism to leverage research activities in a coordinated manner to respond to rural transportation issues among western states related to Technology, Operations and Safety.” Following the conclusion of COATS Phase 4, the WSRTC mission shall be employed in future phases.

1.3. Phase 4 Goals

The primary goal of COATS Phase 4 was to provide research and support activities to help California and Oregon achieve the COATS vision. These activities included: promoting technology transfer, providing deployment assistance, developing ITS device guidance and evaluating the performance of existing deployments.

1.4. Project Tasks

The work plan for COATS Phase 4 consisted of the following nine tasks:

- Task 1: Project Management
- Task 2: Steering Committee Meetings
- Task 3: Western States Rural Transportation Technology Implementers Forum
- Task 4: Integrated Corridor Management – Changed to develop radar speed sign warrants and evaluate the Fredonyer Pass Icy Curve Warning System based on Steering Committee feedback
- Task 5: One Stop Shop Support – as needed
- Task 6: Rural ITS Deployment Assistance
- Task 7: Outreach - conference presentations
- Task 8: Final Report
- Task 9: Workshop Presentation – in conjunction with Steering Committee meeting

Central to the project were the needs and interests of stakeholders within the COATS region. Their input was used to identify what activities would be pursued, as well as provide feedback and information in support of on-going work. WTI managed the project in consultation with the Project Manager and Steering Committee, to ensure integrity and unity in the project approach.

1.5. Report Organization

This report presents a summary of activities completed during Phase 4 of the COATS effort. Specifically, this report provides an overview of the major efforts of the project, including the Western States Forum and other general technology transfer activities, Deployment Assistance, Development of Radar Speed Sign Warrants and the Evaluation of the Fredonyer Pass Icy Curve Warning System. Note that Task 5, One Stop Shop support, was a minimal activity during the course of this work and was summarized in a separate project-specific report. Therefore, it is not discussed in this document.

2. TECHNOLOGY TRANSFER

2.1. Western States Rural Transportation Technology Implementers Forum

The purpose of this project task was to continue the annual Western States Rural Transportation Technology Implementers Forum by providing financial and logistical support for the 2009 and 2010 events. The Forum is focused on delivering high quality technology transfer and networking opportunities for professionals working in design and maintenance of ITS technologies in rural environments. The Forum was conceived to enable ITS practitioners to experience benefits of information-sharing that ITS planners in the COATS region had been realizing over the last several years. This Forum is unique nationally with respect to its audience and technical content, and its origin and development reflects the idea of using COATS as an incubator for innovations in the use of technology to address rural transportation challenges.

The 2009 Forum was held in Mount Shasta, California. Having had positive experiences with the previous Forums, the Steering Committee originally chose to simplify logistics and also hold the 2010 Forum at the Mount Shasta Resort (http://www.mountshastaresort.com/), in Mount Shasta, California. However, the Committee determined that a move from Mount Shasta Resort would be advantageous. The 2010 Forum was held in Yreka, California, at the Holiday Inn Express. This site was chosen primarily because it facilitated participation from other states while remaining within Caltrans District 2, provided an overall cost savings, and put the attendees in closer proximity through the duration of the Forum.

Individual participation at the Forum indicates its growth and success, rising from 15 in 2006, to 22 in 2007 and 39 in 2008. The 2009 and 2010 Forums had 44 and 39 participants respectively. In line with this increase in attendance came diversification of attendees. The initial Forum was attended primarily by Caltrans personnel. By 2009, engineering professionals from California, Idaho, Montana, Nevada, Oregon, Washington, and Wyoming attended the Forum. In 2010, Alaska was added to the list of participant states, though Idaho and Wyoming were unable to participate. Over the last two Forums, along with the eight different states, attendees came from seven Caltrans districts, eight Caltrans divisions, and four universities. One item to note however is that beginning in 2010, Caltrans travel restrictions came into effect, which had an impact on 2010 attendance.

Each year, the Forum has been distinguished by informative, in-depth technical presentations and demonstrations given by rural ITS practitioners. Presenters have delved into how solutions were developed, focusing on applications that have been deployed in the field and are being used in live traffic situations. Success stories have been shared along with failures and problems so that participants learn not only what does work, but also what doesn't work and why. The extended length of the presentations (60-120 minutes) and the informal atmosphere have allowed frank discussion of equipment functionality, vendor claims, system performance, and other key information that practitioners need to know for successful rural ITS projects. The addition of demonstrations and equipment displays has been very well-received and will continue through formal solicitation in the Call for Abstracts. For specific presentation/demonstration topics please refer to the yearly reports completed as part of this task (1,2).

To spread the word about the value of the Forum and enhance marketing endeavors, a concerted effort was made to develop an identity for the Forum, including a logo and a website. The "Save the Date" postcard, the brochure, letterhead, and the website all included a new, unique Western States Forum logo and color scheme (Figure 1).

Figure 1: Western States Forum Logo (horizontal)

A domain name was purchased in the summer of 2009 to be dedicated to the Forum website (www.westernstatesforum.org). The website includes a home page and individual pages that describe the Forum and its history and share pertinent information about the current Forum such as registration, lodging, maps and directions, and things to do around the Forum location. Each past Forum has a set of pages that includes downloadable versions of the technical content and an image gallery. Contact information is also easily accessible. See Figure 2, Figure 3 and Figure 4 for screenshots of the website.

Figure 2: Home page for the Forum website.

Figure 3: Past Forum 2010 page on the Forum website.

After both the 2009 and 2010 Forums, participants expressed a very high interest in attending a similar Forum the following year. Attendees appeared to be satisfied with the length and general format of the Forum, including the small, focused group, detailed presentations, and excellent networking opportunities. The feedback suggests that the Forum is successfully meeting the needs of practitioners and the goals, mission and vision outlined for the Forum.

2.2. Steering Committee Meetings

In addition to the technology transfer completed by the Forum, COATS Steering Committee meetings also provided an opportunity for discussion of current and future ITS activities in the region. It also provided an opportunity for COATS stakeholders to meet and guide planning and decision-making related to the COATS project. The original proposal called for four Steering Committee meetings. In completing this task, two Steering Committee meetings were held in Yreka, California. These occurred on November 4, 2009 and November 9, 2010. Additionally, informal Steering Committee meetings were held in conjunction with the Western States Forum, as a majority of stakeholders were in attendance at each event. Collectively, these meetings allowed for a discussion of the direction and focus of existing project tasks, presentation of initial and final task results, and discussion of future project directions. The Western States Rural Transportation Consortium developed out of these later discussions, with the mission, vision and initial focus of research tasks scoped out during these meetings.

Teleconferences were also held on an as needed basis. This allowed for a travel savings which could then be applied to other aspects of the work, specifically the Western States Forum, travel to local conferences, deployment assistance evaluation, development of radar speed sign guidance and evaluation of the Fredonyer ICWS discussed later in this document. Aside from the organization and conduct of these meetings, associated deliverables included meeting minutes.

2.3. Outreach

Technology transfer outside of the ITS community is also important, and this subtask provided for travel costs and time for one WTI staff member to attend “local” transportation conferences. As discussed in the previous section, attendance at such meetings did occur, with presentations and a presence made at the annual National Rural ITS conference. This attendance was viewed as beneficial in creating new interest in COATS outside of California, where such interest remained strong. The 2009 presentation discussed the history of the COATS effort, while the 2010 presented an overview of the One Stop Shop website, a product which was developed as a spin-off of ideas generated through the COATS effort (3, 4, 5).

3. EFFECTIVE DEPLOYMENT OF RADAR SPEED SIGNS

Radar speed signs have seen increased application in recent years in communities across the United States. The application of radar speed signs has typically been made in a haphazard, unscientific manner, usually involving subjective judgment and only rarely supported by engineering studies. The devices are typically placed where there is a perceived problem, yet decisions to place the devices are rarely accompanied by efforts to quantify or otherwise understand the problem itself, let alone the potential effectiveness of a radar speed sign in addressing it. The excessive use of signage to solve any speeding-related problem, real or perceived, could lead motorists to disregard the signage in the long term. Consequently, it was necessary to establish criteria regarding when and how radar speed signage should be deployed to address safety and speed issues effectively. The work completed by this task established what situations warrant radar speed signs, whether they have been effective in similar applications, where such signs should be located (both setting and placement), and how they should be procured (specifications), operated and maintained. The following sections summarize the work completed during this specific COATS task. The final project report (6) contains further detail on the work completed during the course of this project.

3.1. Warrants

3.1.1. General Guidance

General guidance warrants apply to cases where a radar speed sign may be used to address excessive mean speed and 85th percentile speed issues, ADT levels, speed limit compliance issues, accident history, pedestrian presence, and existing posted speed limits. The warrants developed for this level of guidance included:

- **85th percentile speed –** A radar speed sign may be considered when the observed 85th percentile speeds at a site exceed the posted speed limit by 5 mph or more.
- **Mean speed –** A radar speed sign may be considered when the observed mean speeds at a site exceed the posted speed limit by 5 mph or more.
- **Average daily traffic (ADT) –** A radar speed sign may be considered when ADT exceeds 500 vehicles.
- **Accidents –** A radar speed sign may be considered at sites exhibiting a correctable speeding-related accident history within a recent time period.
- **Pedestrians –** A radar speed sign may be warranted at sites with a pedestrian-related accident history.
- **Posted speed limit –** A radar speed sign may be considered in conjunction with other warrants when the posted speed limit at a site is 25 mph or greater.

3.1.2. Location-Specific Guidance

Location-specific guidance applies to the use of radar speed signs in school and park zones, work zones, and general street locations such as transition zones, curve warning sign locations, and signal approaches. The warrants developed for this level of guidance included:

- Schools and parks

  - A radar speed sign may be considered for use within one-half (1/2) mile of a school zone or park, and
  - A radar speed sign may be considered when the posted speed limit in a school zone or park area is 15 mph or greater, and
  - A radar speed sign may be considered when the 85th percentile speeds in a school zone or park area exceed the posted speed limit by 5 mph or more, or
  - A radar speed sign may be considered when the observed mean speeds in a school zone or park area exceed the posted speed limit by 5 mph or more, or
  - A radar speed sign may be considered when ADT exceeds 500 vehicles, or
  - A radar speed sign may be considered to supplement a conditional speed limit already in place (e.g., a sign stating "Speed Limit 25 when Children Present")
- Street conditions
  - Transition zones – A radar speed sign may be considered in conjunction with other warrants where a speed transition zone exists (high to low speed limits).
  - Curve warning – A radar speed sign may be considered in conjunction with other warrants where a curve speed warning advisory sign exists (high to low speed).
  - Signal approach – A radar speed sign may be considered in conjunction with other warrants for high-speed signalized intersection approaches where the speed limit exceeds 45 mph.
- Work zones
  - A radar speed sign may be considered when the posted speed limit in a work zone is 35 mph or greater, and
  - A radar speed sign may be considered when the observed mean speeds in a work zone exceed the posted speed limit by 10 mph or more.
  - A radar speed sign may be considered when the observed 85th percentile speeds in a work zone exceed the posted speed limit by 10 mph or more.
  - A radar speed sign may be considered in work zones with a history of speed-related accidents.

3.1.3. Specifications

In addition to developing warrants for the use of radar speed trailers, specifications were developed for such equipment to guide practitioners in future purchases and deployments. The specifications developed related to the physical and functional specifications for both permanent post-mounted radar speed signs (and portable post-mounted signs) as well as trailer-based radar speed signs. Applying these specifications would help in improving the uniformity and standardization of the equipment procured and deployments pursued by agencies. While, a comprehensive set of specifications is provided in the project report, a sample of these specifications included the following:

- Dimensions – shall not exceed 36" in width, 48" in height and 12" in depth.
- Numeric display – shall consist of two 7-segment amber LED numerals.

- LEDs – shall be Institute of Transportation Engineers (ITE) amber in color.
- Wavelength from 590 to 600 nanometers.
- Rated for a life of 100,000 hours or more of continuous illumination.
- Shall be 2,250 candela per square meter (cd/m^2) or higher per California test 606.
- Numerals shall be eighteen (18) inches tall.
- All sign system functions shall be controlled by a dedicated on-board removable solid-state computer.
- The numeric display range shall be 0 to 99 mph.
- Display shall be capable of showing the speed of an approaching vehicle and showing a "blank-out" display, which has no visible message.
- Display must be highly resistant to damage from thrown or launched projectiles.
- Display window shall be ¼" minimum thickness shatter-resistant polycarbonate.
- Display and/or electronics enclosure shall be ventilated NEMA 3R compliant, or better.
- The radar sign's operational temperature shall be -30° to 60° Celsius (-22° to 140° Fahrenheit) at a minimum.
- Only brass and stainless steel tamper-proof fasteners shall be employed in sign fabrication.
- Sign exterior shall be powder coated with seaside environment quality materials and processes.
- Display shall be wind load rated at 100 mph when installed to the manufacturer's specifications.
- The enclosure shall have a label with the manufacturer's name, model number, serial number, date of manufacture and the rated voltage, current, power and volt-amperes, if applicable, permanently attached to the unit.

3.2. Recommendations

The primary recommendation of this work is to employ the developed warrants in a systematic manner. To a large extent, the warrants presented cover a wide range of the deployment settings already pursued in California. Where the warrants likely differ from current practice is in the call for different thresholds to be met before deploying signage. For example, mean speeds should be measured at a site of interest and be observed to exceed posted limits by five miles per hour *before* a deployment is considered. Currently, 85^{th} percentile or mean speed measurement is likely not occurring; rather, a sign is deployed to address a resident complaint or a problem perceived by the public (or police or traffic engineers), but not confirmed. Employing the warrants developed in this work will lead to a more systematic approach to the use of radar speed signs and, potentially, greater acceptance of and compliance with posted speed limits by the driving public.

Application of the developed specifications could serve as a de facto baseline for future radar speed sign purchases throughout California. The specifications represent a minimum that should be required by agencies when considering a radar speed sign purchase. They detail all aspects (electrical, dimensional, luminary, performance, etc.) of radar speed signs (and trailers for mobile units), providing purchasers who may not be familiar with such devices with specific parameters to meet in procurement. Applying these specifications would help in improving the uniformity and standardization of the equipment procured and deployments pursued by agencies.

4. DEPLOYMENT ASSISTANCE TASK

Through COATS area research efforts, several web-based research products have been developed, including the WeatherShare system, the Integrated Corridor Management Clearinghouse (ICM) system, the One Stop Shop for Traveler Information system (OSS) and the Integration of Aviation Automated Weather Observation Systems (AWOS) with Roadside Weather Information System (AWOS/RWIS). These systems have been recognized as valued products in improving transportation services. Currently these products are being used while running in a laboratory environment and many of the factors related to transitioning them to a production/deployment environment have not previously been fully addressed.

One of the major decisions that need to be made when moving a web based product from the laboratory environment to the production environment is that of determining where to host the system. Host selection, and pricing, is dependent on the system resources and capabilities needed including bandwidth in and out of the host, storage space, and processing power required. To make this decision, accurate information about the current system configuration and usage must be compiled. Since usage of web based products can be variable and dependant on numerous factors including increased advertising of the site, increased capabilities added to the site, and in the case of a site such as WeatherShare, weather conditions that can cause spike in usage, estimates of typical current usage as well as future usage should be made.

Software that was developed in a research environment should be reviewed and hardened to run efficiently in a production environment. Best practices should be applied to ensure maximum efficiency of data manipulation and web page display. Through the deployment assistance task of COATS Phase 4, these issues were examined, enumerating the considerations necessary to take a web based system from a laboratory environment to a production environment and applying this knowledge to the WeatherShare, ICM, OSS, and AWOS/RWIS systems to determine the available options to transition these systems to a production environment. The final project report (7) contains further detail on the work completed during the course of this project.

4.1. Approach

The transition of a web based product from the laboratory environment to the production environment requires that decisions be made and steps taken to ensure a reliable and maintainable final system. These steps are outlined below.

- Host requirements. One of the requirements of a web based product is that the software be hosted on an Internet-connected server. In the development or laboratory environment the system is typically hosted on a server affiliated with the product developer. For the production environment there are a number of options available, including leaving the system in the development environment, using a traditional hosting option, or using a cloud hosting option similar to Amazon's Elastic Compute Cloud. Selection of the best option is dependent on the needs, present and future, of the web based product in question, as well as the cost.
- Networking. To properly evaluate the hosting requirements and cost, estimates of the system's bandwidth requirements should be made. The two components that make up the

overall bandwidth are the data going into the server and the data going from the server to clients.

- The data coming into the server is easier to quantify since it is retrieved by the system from predefined sources at predefined intervals. It can still vary due to format and coverage changes at the source. At this point, user requests (typically HTTP GET) are negligible in comparison to content data retrieved by the system from external sources.
- The data going from the server to the clients can be a little harder to characterize due to its variability both in terms of number of users and the requests that each user may make. The number of concurrent users and the number of pages accessed by each user can have a great impact on the amount of outgoing data. To characterize the data going from the server to the clients the project team estimated the amount of data transferred to the client for each web page served up as well as the amount for each page update and the update frequency. This data can then be used to estimate user bandwidth usage based on one or more typical uses. Note that usage can vary greatly depending of the system. WeatherShare, for instance, tends to show greater usage during times of bad weather. Consideration of how typical use, worst case use, and potential growth of the user base should all be taken into account when estimating host bandwidth requirements.

- Storage. Similar to bandwidth, storage space needed on the host system should also be determined prior to selecting a hosting option. There are several components that make up the storage requirements. The software storage size is the cumulative size of all the executables, configuration files and scripts that are needed to gather data and display the web pages. The data storage can be classified as static and dynamic. The static are reference data that is unchanged barring growth of the scope of the system. The dynamic data is regularly updated as part of the normal operation of the system and for the case where archived data is saved and will keep growing. The amount of data that is saved and how much data is archived and for how long are all parameters that are needed when determining the host storage requirements.
- Processing. The processor utilization should be measured and documented. Although web based applications don't tend to be thought of as processor intensive, some of the operations that are used to manipulate the data prior to presentation can present a load on the processor. This load should be quantified to be sure that adequate processor power is allocated by the host. Where possible, processor utilization data should be separated by functional use.
- Software. All software required by the host to run the system needs to be documented. This includes operating system type and version as well as any system or third party modules that are required. License requirements or restrictions need to be evaluated. Potential hosts must support these software requirements.
- Software revision. During the research and development phase of a web based project the emphasis is on meeting the needs of the users and the research requirements of the project. There are typically many changes in the software as the data to be presented is refined and the presentation methods are modified to more precisely meet the needs of

the users. During this cycle of changes it is easy for the underlying code to become fragmented and inefficient. Prior to production deployment the software should be reviewed, and modified/improved (refactored) where necessary. The goals of this review should be to simplify the code for ease of understanding and support, optimize the code for improved performance, use all available techniques to maximize the efficiency of the data transferred into and out of the server, and to review any third party products used with respect to licensing requirements. Improvements could include:

  - Compression of information passed between client and server and only passing information that is requested by the client to minimize the necessary bandwidth and increase page display speeds.
  - Removing redundant processing on the server to minimize the load and process new data as efficiently as possible.
  - Reviewing storage requirements to remove redundant storage, re-evaluate storage and archiving requirements and speed up data access.
  - Consolidate and minimize the size of scripts passed between the server and client to reduce the necessary bandwidth an increase the speed at which pages are rendered.
  - Review data update intervals for data retrieved by the server to be sure it synchronizes efficiently with the refresh intervals of the source data.

- <u>Documentation</u>. The documentation developed for research projects is generally sufficient to demonstrate why a particular outcome resulted. However, details are often lacking regarding the “nuts and bolts” that would be essential in a production deployment (i.e. an active, publicly advertised website) of the research product, including information such as source code and user documentation.

<u>Product support</u>. For many of the research products being considered for implementation/deployment, product support is a vital aspect of product viability. One shortcoming of the traditional product licensing model is that product support can vanish if a licensee goes out of business. Questions that should be asked during this step include how can product support be sustained while maintaining a viable business model? Similarly, how can a web application be maintained long term in the absence of a mechanism to continually handle support needs?

4.2. System Hosting Requirements

The following tables summarize the network and storage needs of the combined WeatherShare, ICM, OSS and AWOS/RWIS systems. This data can be used to evaluate the offerings from various hosting options.

	Data in	Data out	Total
WeatherShare with Current Coverage Area	62,779 MB (61.30 GB) per Month	696 MB (0.68 GB) Per Month	63,475 MB (61.99 GB) per Month
ICM	20,751 MB (20.27 GB) per Month	200 MB (0.20 GB) Per Month	20,951 MB (20.46 GB) per Month
OSS	See ICM.	379 MB (0.37 GB) per Month	379 MB (0.37 GB) per Month
AWOS/RWIS	20,751 MB (20.27 GB) per Month	200 MB (0.20 GB) Per Month	20,951 MB (20.46 GB) per Month
Total	104,281 MB (101.84 GB) per Month	1,475 MB (1.44 GB) per Month	105,756MB (103.28 GB) per Month

Table 1: Total Networking Bandwidth

	Program Space	Static Data	Dynamic Data	Total
WeatherShare	37 MB	18,857 MB	29,162 MB + 1170 MB per month	48,056 MB + 1170 MB per month
ICM	198 MB	13 MB	19.69 MB + 2.4 MB /month	230.69 MB + 2.4 MB per month
OSS	99 MB	NA	NA	99 MB
AWOS/RWIS	148 MB	567 MB	NA	715 MB
Total	482 MB	19,437 MB	29,181.69 MB + 1172.4 MB per month	49,100.69 MB (49 GB) + 1172.4 MB per month

Table 2: Total Data Storage

The current hardware configuration has been running and shown to have adequate processing and memory capacity and could be used as a base line for host system requirements. It is noted that while this system has adequate spare processing and memory resources, expansion of the web applications in terms of geographic coverage or functionality may necessitate an increase in storage capacity.

4.3. Software Revision, Documentation and Support

Prior to deploying any software system in a production environment the software should be reviewed and reworked where necessary to ensure reliability and efficiency. While the systems running in a research environment have proven their worth, they are generally used by a limited number of users. When migrating systems into a production environment with the potential for a greater number of users it is important to review all the code making up the system and ensure that maximum efficiency is achieved. This is important for both server side code for efficient utilization of system resources and client side code to improve the user experience.

Systems being moved into a production environment need to have adequate documentation so that the system can be maintained outside of the research environment. The web based systems examined are designed to be intuitive to use and therefore contain only a minimal set of user documentation. They have minimal system/operation documentation. Thorough system documentation is essential for the maintenance and support of a production system.

The following are examples of the types of things that should be included in the system/operation documentation prior to deploying a system in a production setting.

- Data sources. All data sources should be documented including the access methods and any authentication requirements. Update intervals for the data sources should be documented as well as the update intervals for retrieving the data.
- Database. The database structure should be documented in detail as well as authentication and access procedures. Backup/restore routines and policies should be documented.
- Code documentation. A document outlining all the scripts and source code needed to run the system should be created. All dependencies should be documented including system, application and library dependencies.
- Additional system components. All additional or third party software components that are utilized should be thoroughly documented.

When deploying a web based system to a production environment provisions need to be made for ongoing support of the system. Some of the support issues that need to be considered are:

- General system monitoring. The system needs to be monitored periodically for overall operation health. This should include monitoring logs for any system or program errors and ensuring that successful data backups are occurring as intended.
- Data source changes. Systems that import data from external sources are dependent on the location and structure of that data. If/when changes are made by the owner of the external data, code modifications will need to be made to accommodate these changes.
- Provisions need to be made for applying various operating system and security updates. This should include testing on a development platform prior to deploying to a live system.

4.4. Identified Options

There are several options for external hosting of a web based product including shared hosting, virtual servers, dedicated servers, and different types of cloud based dynamic servers.

Shared hosting is generally the least costly; however, these options are generally marketed toward smaller sites and don't necessarily meet the system resources needs for our purposes.

Virtual servers divide up the physical resources of a server into multiple virtual servers. While these options tend to be less costly, ranging from $30-$60/month, they generally have smaller available disk, processor and memory capacity options, so they won't be considered here.

Dedicated servers are leased servers at a hosting facility. Some server administration can be done by the provider as an additional service. This option offers a fair amount of flexibility in configuration; however, you are leasing a fixed hardware configuration so you must attempt to take into account future expansion when initially sizing the server. Using the existing development server as a base line, pricing for a similar system from 1and1.com that includes 2.3

GHz Quad core processor, 8 GB RAM, 1,000 GB of storage and a monthly bandwidth allotment of 4000 GB would cost about $200 per month. A similar offering from Inmotion hosting with 500 GB of disk storage and 2500 GB of bandwidth allotment would cost about $300 per month. While both of these options offer less CPUs and less memory than the current development system, based on the system usage for the current system (see Section 3.2) there should be adequate resources for the current and near term future needs. Both offer a much higher monthly bandwidth usage then we currently require and this should be able to handle increased usage of the sites as well as an increase of data into the system.

There are a few different flavors of cloud based dynamic servers. Cloud based servers logically connect the resources from any number of servers to create a flexible virtual server. These servers offer the ability to re-provision the system resources as required capacity grows or shrinks. Two types of cloud based server options will be examined below.

1and1.com offers their 1and1 dynamic cloud server which offers similar configuration options to their dedicated server, however it allows you to modify your configuration as the need arises. For a Quad-core system with 8 GB of RAM, 500 GB disk space, and 2000 GB per month of bandwidth the cost would be about $240 per month. As an example, raising the disk space to 700 GB and the RAM to 15GB would increase the cost to about $350 per month. While this system offers a fair amount of flexibility in configuration, it is primarily geared toward infrequent modifications and care must be taken in picking a host so that you don't outgrow all the available choices.

A second type of dynamic cloud server is the elastic compute cloud offering by Amazon. The Amazon Elastic Compute Cloud (EC2) is a virtual computing environment that is designed to allow the expansion or shrinking of resources quickly as requirements or usage change. The application can be designed to automatically scale itself if desired and you only pay for the resources that you use. Pricing varies depending on the options chosen and used. Pricing for a large instance, defined by Amazon as: 7.5 GB of memory, 4 EC2 Compute Units (2 virtual cores with 2 EC2 Compute Units each), 850 GB of local instance storage, 64-bit platform, is $297 per month. This includes 200 GB per month of incoming bandwidth and 5 GB per month of outgoing bandwidth. This does not include any dynamic expansion services, which should be investigated further. There are numerous options for monitoring and modifying the system that could be advantageous given the usage patterns of the systems examined with higher usage during times of bad weather and moderate to low usage other times.

4.5. Host Recommendation

The three viable options for external hosting as outlined were: dedicated server, dynamic cloud server, and elastic cloud server.

The dedicated server option generally is the least costly; however, it is also the least flexible. Expansion or contraction of system resources can only be done by leasing a different dedicated server and may be subject to server availability. The monthly costs are fixed, however, and can be budgeted for on a long term basis.

The dynamic cloud option is more flexible allowing you to start with a base server configuration and then expand or contract resources as needed. The cost for a dynamic system may be more than an equivalent dedicated server; however, this option could allow you to start with a lesser configuration, with a less expensive cost, and increase capabilities when needed. Depending on the amount of resources used over an extended period of time, the long term costs of a dynamic cloud may be equivalent or less than a dedicated server. Depending on the provider there can be ceilings on the amount of resources that can be acquired and they may be subject to resource availability. Also with the variability of costs, depending on the resources used, budgeting for monthly costs can become more complicated.

The Amazon Elastic Compute Cloud option offers the most flexibility and expansion capability. While it is more costly than an equivalent dedicated server, it may allow for a lesser configuration to be used during times of normal activity with expansion only as needed. Since you pay for the resources used, the costs over a longer period of time may not be that much higher than a dedicated server. Due to the size of Amazon, the available options are extensive and need to be fully understood n order to fully take advantage of them. The upper end for available resources is higher than smaller service providers. Again, the variable nature of the costs, due to the expansion or contracting of system resources, can make budgeting for monthly costs more complicated. Ultimately for systems such as the ones being examined here, this may be the most intriguing option as it will allow adjustment to the variable nature of usage and easy reaction to added capabilities of the system.

4.6. General Recommendations

Prior to proceeding with external hosting, it is recommended that the general and specific changes documented be further addressed and implemented to optimize the system. Specific recommendations such as implementing server-side compression on text files served by the web server would immediately improve performance for users. Other items such as whether or not to archive data must be further discussed to weigh the pros in terms of system performance and scalability with the associated, reduced functionality. Code-refactoring should be implemented as time and funding allow. And, greater effort and emphasis needs to be placed on system documentation and on-going support and maintenance needs.

5. EVALUATION OF THE FREDONYER PASS ICY CURVE WARNING SYSTEM

The Fredonyer Pass Icy Curve Warning System was deployed by Caltrans to increase motorist vigilance and reduce the number of crashes occurring during icy pavement conditions by providing warnings in real-time. The ICWS consists of pavement sensors to detect icy conditions, in combination with dynamically activated signage to provide motorists with real-time warning when icy conditions are either imminent or present. The system is intended to alert motorists of icy conditions, eliciting a decrease in vehicle speeds during such conditions. Consequently, lower vehicle speeds are expected to translate to reduced crashes along the length of the curves which have presented safety challenges in the past.

While the system was initially installed during the summer of 2002, it did not reliably operate in the manner envisioned by Caltrans and required an extensive rebuild, which began during the spring of 2006. The rebuild and subsequent testing and validation of the system required a significant amount of time. As a result, the ICWS was not considered fully operational and reliable until March, 2009. The work presented in this project evaluated the performance of the ICWS following the rebuild, focusing on the metrics of speed reduction under various conditions and safety performance through crash reductions. In addition, a review of literature pertaining to road condition warning systems was made, along with documentation of roadway maintenance, ITS system maintenance and CHP perspectives of the ICWS.

Through the evaluations performed by this task, Caltrans should have a better understanding of how the Fredonyer Pass ICWS is meeting its primary objectives of reducing vehicle speeds during icy conditions and reducing crashes along the curves of interest and in their vicinity during those same icy conditions. The final project report (8) contains further detail on the work completed during the course of this project.

5.1. Results

5.1.1. Speed Analysis

The results of the statistical analysis of speed data suggest that the system is working as intended and that vehicle speeds are significantly lower. This was particularly true of speed during clear, cold and dry weather conditions, when a driver would not necessarily expect to encounter ice. As one would expect, the system also appears to have contributed to lower vehicle speeds during weather events (i.e., snow) as well. Speed data were examined to determine whether statistically significant differences of 0 mph, 3 mph and 5 mph existed when the system was on versus off under various conditions. T-tests were employed to perform the statistical evaluations.

As one would expect, mean speeds were significantly different by greater than 5 mph when the system was on versus off. In other words, when the system was turned on and providing a warning of ice conditions, vehicles traveled at slower speeds. Of course, this collective analysis told little about the performance of the system under different conditions, namely during the day and night, as well as during different weather. When speed data were examined by system state and time of day (day versus night) in combination, it was once again found that mean speeds were significantly different by greater than 5 mph. The general mean speed reductions observed ranged between 5.19 mph and 8.66 mph during the day and 5.72 mph and 8.30 mph during the night when the system was turned on.

When general wet weather (snow, rain, etc.) conditions were evaluated, it was found that mean speed reductions were significantly greater than 5 mph. During the day, mean speeds during wet weather fell between 6.20 mph and 10.73 mph when the system was on. At night, mean speeds during wet weather fell between 10.34 mph and 16.14 mph when the system was on. Such changes in vehicle speeds were expected during inclement weather, when poor visibility and the potential of reduced pavement friction combined to lead motorists to drive more slowly. Consequently, the contribution of the ICWS to the overall drop in vehicle speeds during wet conditions was difficult to extract from other contributing factors.

The real effectiveness of the Fredonyer ICWS was its impact on reducing vehicle speeds during conditions when ice was present but unexpected by drivers. Such conditions, called clear, cold and not dry in this work, were times when snow melting or general water/ice pooling from the wet and cold environment of the curve locations may produce runoff across the roadway in the target curve and result in ice formation. When the base hypothesis that mean speeds differed from one another overall (0 mph) was examined, statistically significant differences in mean speeds when the system was on versus off during clear, cold and not dry conditions during both the day and at night were observed. These differences continued when the hypothesis of mean speed differences exceeding 3 mph was examined. However, only a limited number of mean speed differences were found to be statistically significant for speed differences of greater than 5 mph. Consequently, it appears that the ICWS is prompting motorists to reduce their speeds by less than or equal to 3 mph in conditions where icy roads are not necessarily expected. Whether this reduction represents a modification that translates into long-term safety benefits (i.e., reduced crashes in the curves of interest), particularly during clear, cold and dry conditions, remains to be seen. As the speed readings employed in this evaluation were collected at sign locations in advance of the curves of interest/concern targeted by the ICWS, the true changes in motorists' speeds throughout the course of the curve remain unknown. It is possible that the observed changes in mean speeds reported here are translating into even more significant reductions by motorists as they enter and traverse each curve.

5.1.2. Safety Analysis

In order to determine the safety effects of the ICWS, an observational before-after study using the Empirical Bayes technique was employed. This evaluation determined the effect of ICWS on crash frequencies. The results found that the deployment of the ICWS reduced the number of annual crashes by 18%, which corresponds to an Accident Modification Factor of 0.82. As no other changes occurred along the study segment (additional safety improvements, geometric changes, etc.), it is reasonable to attribute this observed safety improvement to the ICWS. Additionally, a crash rate method was used to investigate the effect of the ICWS on crash severities, with a focus on ice-related accidents. The results indicated that the ICWS has reduced crash severities. This reduction in severity is likely the result of vehicles traveling at slower speeds as the result of the ICWS in the event of a crash. As a result of reduced crash severities, the system was estimated to provide safety benefits of $1.7 million dollars per winter season during the "after" deployment study period (2008-2009, on account of time lag in crash data availability).

While the safety results are encouraging, caution is warranted in their interpretation. First, because of the nature of crash databases and data availability, combined with the timing of this evaluation, only 1 ½ years of after period data was available for analysis. While the Empirical

Bayes approach employed in this work has been developed to accommodate such cases of limited data, it would be advisable to revisit the safety performance of the Fredonyer ICWS at some point in the future when more years of crash data are available. Second, while the lack of any additional construction/safety improvements aside from the ICWS allowed for the assumption to be made that most of the observed safety improvement along the study segment could be attributed to the ICWS, future work should consider a more focused evaluation. Such an analysis would consider only the winter months and require the development of a specific Safety Performance Function.

5.1.3. System Perspectives

In addition to evaluating the performance of the system, feedback on the operation and perception of the ICWS was obtained from a number of viewpoints. These included winter maintenance personnel (Caltrans), ITS Engineering staff (Caltrans) and California Highway Patrol officers.

From the perspective of Susanville maintenance, the ICWS is an improvement over typical static metal signage. Observations made over time have indicated that as the winter progresses, the system works better. The use of additional pavement pucks for detection of conditions in multiple lanes could improve system accuracy and reliability. The data produced by the ICWS is not presently employed by maintenance forces for any activity, although the CCTV camera associated with the system's RWIS at the summit is used frequently to obtain visual information on present conditions.

Feedback by ITS Engineering staff indicated that following the rebuilding of the ICWS, it is generally functioning as expected. However, observations over several years of operation have indicated that the system has difficulty identifying road conditions during the early winter. The use of additional sensors in such cases would address this issue. Also, employing data from supplemental sensors (i.e. air temperature, precipitation, etc.) could possibly allow the system to compensate for times that roadway surface temperature and condition data is not sufficient in identifying potential icing conditions. When considering similar systems for deployment elsewhere, it is especially important to select roadway sensors that can be tested/calibrated easily and to employ data collection equipment in the system that uses open and easily programmed software.

In general, the system requires different maintenance activities throughout the year. A visual inspection of the surface sensors is made before each winter season. This inspection has found that crack sealer has been applied over sensors in some cases, requiring a cleaning with acetone. During this check, each sensor is also tested for proper operation by manually applying water. Experience has found that the surface sensors do fail and must be replaced. This represents a major operation requiring core drilling and saw cuts to the pavement. Puck replacement has also led to the identification on different installation needs, such as taping off the puck to avoid getting epoxy on the sensor during installation. At the controller location, the fenced enclosure has made it harder to change batteries out because of the extra distance required to carry them to and from the cabinets. The fencing also traps snow inside the enclosure, making access to the cabinets more difficult during winter when access is often required. These items should be kept in mind when designing future systems.

Feedback provided by CHP indicated that drivers appear to be slowing down when the ICWS is on (particularly in vicinity of the targeted curves). This is only perception though, and there has been no analysis performed by CHP (e.g., on ticket records) to verify whether it is in fact the case. It was also believed that crashes over the pass have dropped in recent years, although again, no analysis of data has been performed to confirm this view. The thoughts of CHP on this drop were that it could be related to the ICWS, as well as continued manned chain control policies employed by Caltrans. In general, the system appears to be accurate in indicating ice conditions. The view of the system overall is that it is good to have a warning device up on the pass for bad weather.

5.2. Recommendations

A number of recommendations for future work and monitoring can be made based on the work completed during this COATS task. First, based on the short period of "after" crash data that was available for use in the crash analysis during this work, it would be advisable to revisit the crash trends at a future date. A future evaluation would once again examine the effectiveness of the ICWS in reducing crashes, but would employ a longer duration of "after" period data, from three to five years or longer. The Empirical Bayes approach employed in this report could once again be used for that evaluation, examining crash data from throughout the year. Such work might also consider only winter months and employ the development of a specific Safety Performance Function (SPF). The development of such SPF's can be quite costly and time intensive, which is why such an approach was not employed in this work. However, through the development of an SPF specific for ICWS', the performance of ICWS' deployed elsewhere could be more easily evaluated. Regardless of the approach employed, the evaluation of crash trends over a longer period of time is necessary in order to understand the long term impacts and effectiveness of the ICWS. While initial results have indicated that it has had a positive impact on reducing crashes over Fredonyer Pass, that does not necessarily mean that over a longer term this will hold true. By understanding the long term impacts of the ICWS on crashes, a better understanding can be developed regarding whether similar systems could be deployed elsewhere to address similar roadway ice issues.

Coincident with planning for future safety (and speed) evaluation, it is recommended that Caltrans District 2 maintain records of chain control levels going forward. These records can consist simply of saved .pdf files from the chain control report log. These files were used during the course of the analysis presented here, and will be sufficient for future work as well. The key is to save these data/files on an annual basis for future use.

Secondly, an evaluation of mean speed trends would be advisable. Again, while the ICWS appears to be effective in producing a reduction in vehicle speeds under different conditions, particularly clear, cold and not dry conditions when ice isn't expected, the long term effectiveness of the system on speeds remains unclear. While this report evaluated data from two full winter seasons as well as the end of one partial season (spring 2009), it is possible that over a longer period of time, the system may lose some effectiveness, with vehicle speeds rising. Conversely, as the system remains deployed over a longer period, drivers may come to trust its indications of icy roads and produce further speed reductions in addition to those documented by this work. Without evaluating future years of speed data, long term effectiveness of the ICWS will remain unanswered.

When evaluating speed data in the future, it may also be advisable to collect speeds from the center of each targeted curve. The evaluation presented here only examined speed data from sign locations in advance of each curve. While the reviewed data provides a general sense of driver reactions to the ICWS message, it remains unknown whether, and to what extent, drivers slow down while passing through the targeted curves. Only through the collection of speed data at some point or points in each of the curves targeted by the ICWS can it be determined if drivers slow down to any significant extent (and, if so, by how much) as they pass through the curve. Of course, challenges may exist which make it more difficult to collect such data (e.g. permits to place data collection equipment and/or run power to that equipment on Forest Service lands).

The speed data collected by radar during the course of this project was aggregate and did not classify vehicles by their type. Of course, on a mountain pass, the type of vehicle traveling up or down a grade will play a significant role in the speeds observed. For example, a heavy vehicle will travel much slower upgrade because of its weight when compared to a passenger car, regardless of the presence of curves and potential for ice. Similarly, a heavy vehicle will also travel more slowly downgrade in order to maintain control. The presence of such slow moving vehicles may lower overall average speeds when analyzed collectively with all other vehicles. While this was not viewed to be a problem in this analysis, given the large sample sizes of data examined, it would provide interesting information related to the behaviors of specific vehicle types. Consequently, if possible for future work, data should be collected by equipment which is capable of classifying and binning vehicles by type.

Finally, future work may consider obtaining feedback from the driver population traveling over the pass regarding perceptions of the system and its effectiveness in changing behaviors. This work attempted to reach out to drivers who travel over Fredonyer Pass on their way to work at the local prisons (specifically employees of the High Desert State Prison and the California Correctional Center). These facilities were contacted to seek volunteers to provide brief feedback on the system (experiences, perceptions, views). Unfortunately, no respondents were identified during the course of these contacts to answer questions about the ICWS from a driver perspective. Future work should again attempt to solicit feedback from these sources, as well as any others that may be identified. Past work related to the ICWS has also employed mailed surveys to residents in local communities, and this is another approach that might be considered.

6. CONCLUSION

This report has discussed the various activities during the COATS Phase 4 project. Phase 4 tasks focused on four specific areas: technology transfer, deployment assistance, development of guidance for radar speed signs, and evaluation of an existing deployment. Technology transfer activities were centered on the growth and continuation of the annual Western States Forum. Deployment assistance examined how to transfer web-based research products that are running in a laboratory environment to a production environment. Development of guidance provided warrants for the acquisition and deployment of radar speed signs in a variety of settings to address speeding issues. Evaluation of the existing Fredonyer Pass Icy Curve Warning system examined the safety and speed impacts as well as maintenance aspects of this particular deployment.

6.1. Summary of Major Efforts

The Western States Forum served as a technology transfer platform where informative, in-depth technical presentations could be given by rural ITS practitioners. Presenters delved into how solutions were developed, focusing on applications that have been deployed in the field and are being used in live traffic situations. Success stories have been shared along with failures and problems so participants could learn what does and doesn’t work and why. The Forum has included live demonstrations of rural ITS technologies and “hands-on” question and answer periods. Participants have brought actual ITS equipment and performed informal “show and tell” sessions during the breaks.

The development of radar speed sign warrants sought to establish guidance on what situations warrant radar speed signs, whether they have been effective in similar applications, where such signs should be located (both setting and placement), and how they should be procured (specifications), operated and maintained. Deployment assistance examined how software that was developed in a research environment should be reviewed and hardened to run efficiently in a production environment, documenting the considerations necessary to take a web based system from a laboratory environment to a production environment. This knowledge was applied to the WeatherShare, ICM, OSS, and AWOS/RWIS systems to determine the available options to transition these systems to a production environment. Finally, evaluation of the Fredonyer Pass ICWS looked at the performance of the system following its rebuild, focusing on the metrics of speed reduction under various conditions and safety performance through crash reductions. Through the evaluation, a better understanding of how the system is meeting its primary objectives of reducing vehicle speeds during icy conditions and reducing crashes along the curves of interest and in their vicinity during those same icy conditions was developed.

6.2. Summary of Deliverables

During the course of the Phase 4 effort, a number of deliverables were produced. Specific report documents and memoranda are listed in the References section of this report (1-8). In terms of deliverables produced over the course of the project, these included:

- Quarterly progress reports;
- Meeting minutes (Steering Committee meetings and conference calls);
- Organization and conduct of the Western States Rural Transportation Technology Implementers Forum from 2009 through 2010;

- Annual reports summarizing the Western States Rural Transportation Technology Implementers Forum (1, 2);
- Development of various COATS and Western States Rural Transportation Consortium websites (http://www.westernstates.org/Projects/COATS/ and http://www.westernstates.org/);
- Development, support and final documents associated with the "Effective Deployment of Radar Speed Signs" project (6);
- Development, support and final documents associated with the "Analysis and Recommendations for Optimization and Deployment of WeatherShare and Related Web-Based Projects" (Deployment Assistance) project (7);
- Development, support and final documents associated with the "Evaluation of the Fredonyer Pass Icy Curve Warning System" project (8);
- Conference presentations:
  - *COATS: A Decade of Rural ITS* - 2009 National Rural ITS Conference (3);
  - *The Western States Forum Tech Transfer from the Implementer's Perspective* - 2009 National Rural ITS Conference (4);
  - *Development of a One Stop Shop for Rural Traveler Information*- 2010 National Rural ITS Conference (5);

6.3. Conclusion

The COATS Phase 4 project, running between 2009 and 2011, focused on technology transfer, deployment assistance, development of guidance for radar speed signs, and evaluation of an existing deployment. Technology transfer activities were centered on the growth and continuation of the annual Western States Forum. Since its inception, the Western States Forum has grown both in terms of attendance, as well as in the scope of material being presented and discussed. This event has continued under the scope of COATS Phase 5/Western States Rural Transportation Consortium and is expected to keep providing an intimate forum for the discussion of rural ITS applications, successes, and failures. In providing such a venue for ITS discussion, one of COATS' overriding goals was met: promoting technology transfer.

Deployment assistance examined how to transfer web-based research products that are running in a laboratory environment to a production environment. The work completed during this task resulted in a number of recommendations. Prior to proceeding with external hosting, it was recommended that the general and specific changes documented be further addressed and implemented to optimize the system. Specific recommendations such as implementing server-side compression on text files served by the web server would immediately improve performance for users. Other items such as whether or not to archive data must be further discussed to weigh the pros in terms of system performance and scalability with the associated, reduced functionality. Code-refactoring should be implemented as time and funding allow. Finally, greater effort and emphasis needs to be placed on system documentation and on-going support and maintenance needs.

Development of guidance provided warrants for the acquisition and deployment of radar speed signs in a variety of settings to address speeding issues. Two levels of guidance were developed through this task: general guidance and location-specific guidance. General guidance warrants applied to cases where a radar speed sign may be used to address excessive mean speed and 85^{th} percentile speed issues, ADT levels, speed limit compliance issues, accident history, pedestrian presence, and existing posted speed limits. Location-specific guidance applied to the use of radar speed signs in school and park zones, work zones, and general street locations such as transition zones, curve warning sign locations, and signal approaches. In addition to developing warrants for the use of radar speed trailers, specifications were developed for such equipment to guide practitioners in future purchases and deployments. The specifications developed related to the physical and functional specifications for both permanent post-mounted radar speed signs (and portable post-mounted signs) as well as trailer-based radar speed signs.

Evaluation of the existing Fredonyer Pass Icy Curve Warning system examined the safety and speed impacts as well as maintenance aspects of this particular deployment. Based on the results of this work, two conclusions have been drawn. First, the statistical analysis of speed data suggested that the system is working as intended and that vehicle speeds are significantly lower. This was particularly true of speed during clear, cold and not dry weather conditions, when a driver would not necessarily expect to encounter ice. Second, the evaluation of crash data before and after system deployment found that the ICWS reduced the number of annual crashes by 18%. Additionally, investigation of crash rates indicated that the ICWS provided safety benefits of $1.7 million dollars per winter season during the “after” deployment study period.

7. REFERENCES

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