COMPARATIVE EVALUATION OF AUTOMATED WIND WARNING SYSTEMS

Showcase Evaluation #15

Final Report

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GLOSSARY OF ABBREVIATIONS

AADT	Annual Average Daily Traffic
ATR	Automatic Traffic Recorder
AWWS	Automated Wind Warning Systems
Caltrans	California Department of Transportation
CHP	California Highway Patrol
CMS	Changeable Message Sign
COATS	California/Oregon Advanced Transportation Systems
DMV	Department of Motor Vehicles
FHWA	Federal Highway Administration
HTCRS	Highway Travel Conditions Reporting System
ITS	Intelligent Transportation Systems
MOE	Measure of Effectiveness
MP	Mile Post
NB	North Bound
NOAA	National Oceanic and Atmospheric Administration
ODOT	Oregon Department of Transportation
OSP	Oregon State Police
RWIS	Road Weather Information Systems
SB	South Bound
SRRA	Safety Roadside Rest Area
TMC	Transportation Management Center
VMS	Variable Message Sign

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1. INTRODUCTION

One challenge facing rural travelers is the presence of weather hazards that produce adverse driving conditions at isolated locations. One such hazard is sustained high winds that can cause high-profile vehicles such as recreational vehicles, commercial vehicles, etc. to overturn, and lower-profile vehicles to leave their lanes, jeopardizing motorist safety. Since wind conditions and patterns are defined significantly by local topography, there is limited ability to mitigate the impacts of wind through improved roadway design. Warning drivers of impending cross winds well in advance and implementing measures to reduce operational speeds are other options explored by transportation professionals.

To address localized high cross wind challenges, the Oregon and California Departments of Transportation (ODOT and Caltrans, respectively) have used intelligent transportation systems (ITS) installations to alert motorists of dangerously windy conditions automatically. The warning messages are displayed to drivers at locations where they can stop and wait until the winds die down or where they can decide to take a longer alternate route. Three systems have been deployed in the rural California / Oregon Advanced Transportation Systems (COATS) study area, at the following locations:

- Between Port Orford and Gold Beach, Oregon on US Route 101 between mileposts (MP) 300.10 and 327.51 ("South Coast System")
- On the Yaquina Bay Bridge (US Route 101) between mileposts 141.27 (SB) and 142.08 (NB) in Oregon
- On Interstate 5 in Siskiyou County, California between postmiles 13.2 (Weed) to 45.3 (Yreka)

As these systems represent innovative applications of ITS in a rural environment, a project through COATS Showcase was initiated to evaluate their effectiveness. The evaluation focused on the two Oregon systems, because these two systems were fully or partially automated and operational for the high wind season of 2003-04 (i.e. November 2003 – March 2004). The goals of the automated wind warning systems (AWWS) deployed in Oregon are threefold:

- Improve the safety and security of the region's rural transportation system
- Provide sustainable advanced traveler information systems that collect and disseminate credible, accurate "real-time" information
- Increase operational efficiency and productivity focusing on system providers

This report summarizes the results of this evaluation. The system locations and evaluation methodology are described in Chapter 2. Chapter 3 reviews the impacts of high-winds on motor vehicles. Evaluation results for different measures of effectiveness are presented in Chapters 4 (safety), 5 (motorist surveys), 6 (technology assessment) and 7 (operational benefits). Chapter 8 summarizes the findings of this evaluation and makes recommendations regarding future implementation.

2. PROJECT BACKGROUND

This chapter describes the wind warning systems being evaluated in this project and the evaluation methodology.

2.1. Wind Warning Systems

As mentioned in Chapter 1, there were three automated wind warning systems that were considered in this evaluation:

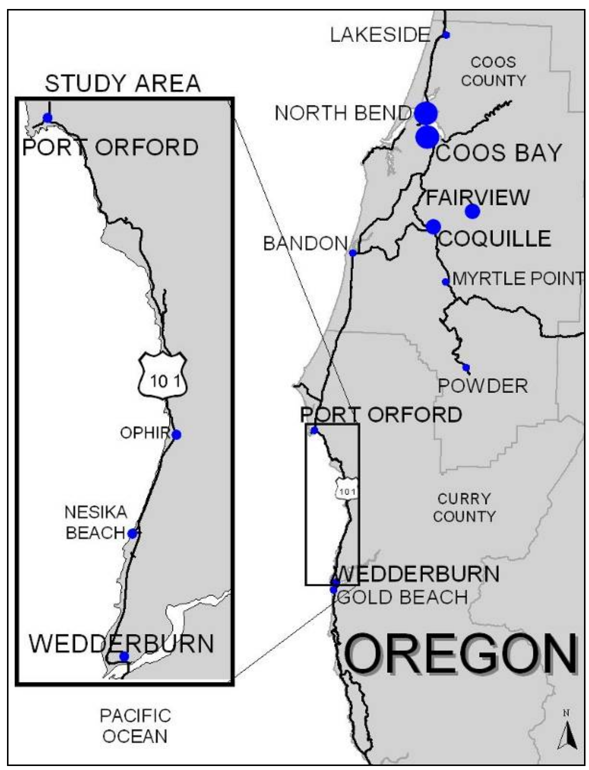
- Between Port Orford and Gold Beach, Oregon on US Route 101 between mileposts (MP) 300.10 and 327.51 ("South Coast System")
- On the Yaquina Bay Bridge (US Route 101) between mileposts 141.27 (SB) and 142.08 (NB) in Oregon
- On Interstate 5 in Siskiyou County, California between postmiles 13.2 (Weed) to 45.3 (Yreka)

The following sections provide more detail on each of these systems.

2.1.1. South Coast System

US Route 101 between Port Orford (MP 300) and Gold Beach (MP 330), shown in Figure 2-1, has been identified as a high wind area. Several times a year, Humbug Mountain (MP 306) experiences high winds topping 120 mph, which poses a safety hazard to high-profile vehicles. The ODOT ITS Unit designed a system that uses a local wind gauge (anemometer) to monitor wind speeds near Humbug Mountain. Prior to implementation of the system, when high winds were detected, maintenance personnel drove to Gold Beach (MP 330) and Port Orford (MP 300) to flip up folded signs that read "CAUTION HIGH WINDS NEXT 27 MILES WHEN FLASHING" and turn on a flashing beacon to warn traffic about windy conditions. The employee would patrol the highway until the winds subsided, and then manually turn off each sign. This system had a high maintenance cost, required a 60-mile round trip to Gold Beach, and was not timely enough.

Figure 2-1: Map of South Coast System



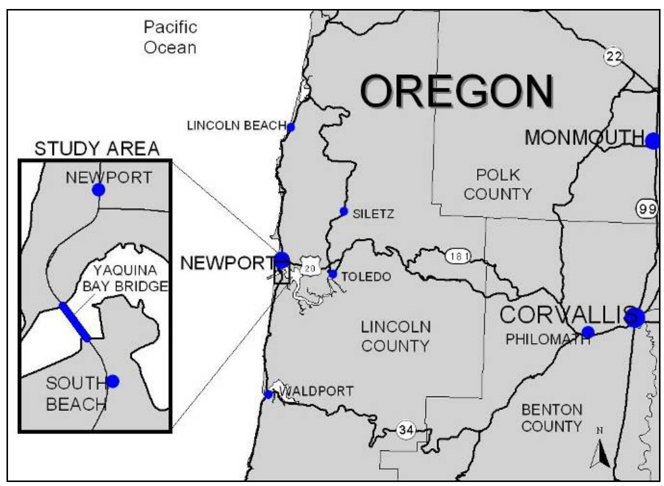
This process has now been automated.

Currently, this system consists of an anemometer that provides continuous input to the controller connected to a flashing beacon on static warning signs located at either end of the corridor. Communication to the two warning signs is automated and is provided using dial-up telephone links. Motorists are informed when average winds of speeds higher than 35 mph are recorded over a given time interval (e.g. 2 minutes). This enhancement has also enabled an automated creation of an instance of severity 0 (zero) incident (for wind speeds between 35 and 80 mph) or a severity two incident (for wind speeds greater than 80 mph) in Oregon's Highway Travel Conditions Reporting System (HTCRS). This incident in HTCRS is then verified by the Traffic Operations Center (TOC) staff. When verified by the TOC staff, the HTCRS warning is posted on ODOT's TripCheck web site.

Project implementation was motivated by the many potential benefits, including equipment cost savings, elimination of unnecessary and possibly unsafe travel by ODOT personnel, and more rapid detection and notification of high-wind conditions, which would improve safety in the corridor.

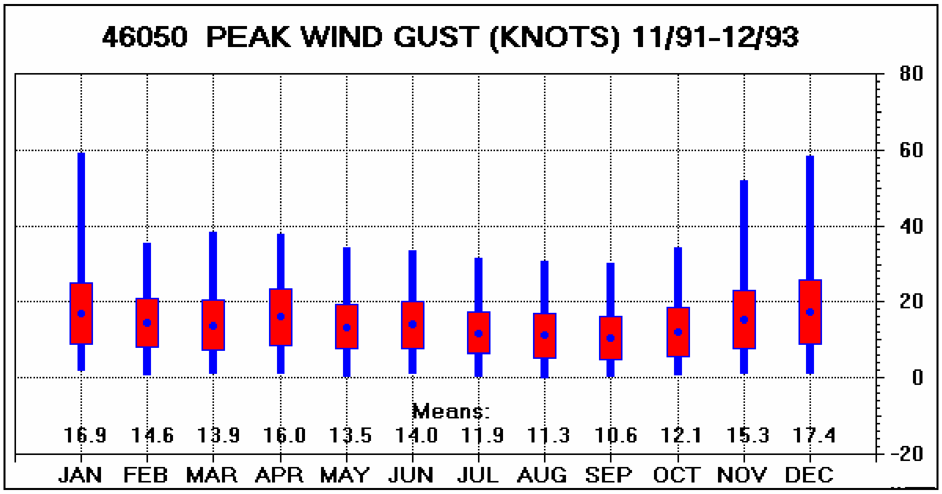
2.1.2. Yaquina Bay Bridge System

Figure 2-2: Location of Yaquina Bay Bridge System



The second AWWS in Oregon was installed on Yaquina Bay Bridge (US Route 101) between mileposts 141.27 (SB) and 142.08 (NB), as shown in Figure 2-2. Several times each winter, wind gusts reaching 80 mph are recorded on the bridge. Figure 2-3 shows the data from the buoy in Yaquina Bay operated by the National Oceanic and Atmospheric Administration (NOAA) for one year. These gusts constitute a danger to high-profile vehicles. ODOT has had a manual process for measuring gusts in the vicinity of the bridge and providing warnings to the public. When gusts or sustained high winds were present, an employee went to the site with a portable anemometer and, if windy conditions were verified, unfolded static warning signs on either end of the bridge. Crossing the bridge to reach the other sign (and then coming back) presented a safety risk for the employee charged with this task. Information tends to not be real-time, and is disseminated by Region 2 Dispatch by faxes. Moreover, there is no historical data on how often high-wind conditions exist and travel restrictions are enforced.

Figure 2-3: Average Gust Speeds for Month of Year



Note: 1 knot is equivalent to 1.2 miles per hour.

(Source: NOAA)

To avoid the safety risks and to improve operations, ODOT has automated the posting of high-wind warnings. The proposed system originally consisted of a local wind gauge connected to small variable message signs (VMS) located at either end of the corridor with different levels of warning. Due to lack of available funding, the current system uses a static sign that reads “Caution High Winds on Bridge When Flashing” and flashing beacons installed on top of the signs. The signs are located to provide sufficient warning for drivers to be able to turn around on existing roads under either end of the bridge. Although the current signs display a fixed message, the system records two different warning levels, as described in Table 2-1. This system also defines the severity of the incident. This severity is automatically recorded in HTCRS, and is then verified by the Traffic Operations Center (TOC) staff. When verified and accepted by TOC staff, a warning message is automatically posted on ODOT’s TripCheck Web site. Faxes are also sent manually to other agencies, and maintenance staff are also notified automatically via pager and / or email. The sign is deactivated when the average wind speed goes below 25 mph. This system will archive data including wind speed, and date and time of warning postings.

Table 2-1: Warning Messages for Yaquina Bay System

Average Wind Speed Range	Warning Message	HTCRS Severity Level
35 to 80 mph	Pending Closure	1
Over 80 mph	Closure	2

2.1.3. Interstate 5 System

Interstate 5 between Weed (postmile 5-SIS-13.2) and South Yreka (PM 5-SIS-45.3) is a four-lane divided interstate highway which serves as an interregional State Highway Extra Legal Load (SHELL) route, and is the only designated route for oversize trucks in Caltrans District 2. This corridor can experience unexpected gusty high winds, as a result of the corridor's proximity to Mount Shasta. During high wind conditions, traffic can encounter severe cross winds that can cause vehicular instability, especially for high profile vehicles. Currently there are static signs with no flashing beacons at either end of this corridor. The static signs are not responsive to real-time weather conditions, and they make less of an impression on the drivers, because they display a message of caution irrespective of wind speeds.

Caltrans has been providing high wind warning messages through two changeable message signs (CMS): one just south of the Yreka interchange for the southbound traffic, and the other at the Abrams Lake over-crossing for the northbound traffic. There is a weather station installed at the northbound Weed Safety Roadside Rest Area at PM 25.7 to make the system responsive to conditions on a real-time basis. Caltrans is in the process of automating the activation of warning messages through these CMS signs by integrating the weather station readings with CMS messages. The CMS also allow greater flexibility in message sets, including the ability to report specific levels of warning, or the actual wind speed. The purpose of this project is to improve traffic safety by providing a system to gather and effectively communicate information on current wind conditions to the traveling public.

Traffic accident data for the project limits are displayed in Table 2-2. A safety analysis was conducted in November 2000 and the recommendation made by the Safety Review Committee was incorporated into the preferred alternative.

Table 2-2: Summary of Crash Data for Interstate 5 System Location, 1997-2000

	Crash Rate (per million VMT)	
	Interstate 5, Siskiyou County PM 13.1 to 45.2	**Statewide Average**
Total Accident Rate	0.57	0.46
Fatal Accident Rate	0.008	0.016
Fatal + Injury Accident Rate	0.22	0.21

2.1.4. Summary of Systems

Table 2-3 summarizes the different characteristics of these three systems. All three systems are currently active. The two systems on US 101 in Oregon are automated, while the system on Interstate 5 in California is operational but not fully automated.

Table 2-3: Summary of Wind Warning System Characteristics.

Charactersitics of the System	AWWS at Yaquina Bay Bridge, OR	AWWS at South Coast, OR	5, Siskiyou County, CA
Flashing/Non-Flashing	Flashing	Flashing	CMS
Static/Dynamic	Static (to be upgraded to CMS)	Static	Dynamic (CMS)
Message sent to sign (manual / automated)	Automated	Automated	Manual (To Be Automated in 2005)
Message posted on Web (manual / automated)	Semi - Automated	Semi - Automated	N/A
Archiving of the Wind Data	Yes	Yes	No
TOC notification of sign activation (manual / automated)	Automated	Automated	To be Automated
TOC notification of wind data (manual / automated)	Automated	Automated	Automated
Location of signage	US Route 101, MP 141.27 (SB) and 142.08 (NB)	US Route 101, MP 300.10 to 327.51	Interstate 5, PM 13.2 to 45.3, Siskiyou County

2.2. Evaluation Methodology

These systems represent innovative applications of intelligent transportation systems (ITS) in a rural environment; consequently, it is important to know whether these systems are effective in improving user safety and the quality and dissemination of traveler information. It is also important to identify other benefits such as personnel time savings due to automation of some of the processes. Because these locations are within the rural California/Oregon Advanced Transportation Systems (COATS) study area, they were evaluated under the COATS Showcase evaluation project. The COATS Showcase project, started in 2000 as a partnership between the California Department of Transportation and the Western Transportation Institute, sought to build on the successful rural COATS ITS planning and deployment effort that engaged stakeholders in southern Oregon and northern California, in a geographic area spanning from Eugene, Oregon to Redding, California. COATS Showcase sought to advance rural ITS by demonstrating and evaluating innovative ITS concepts.

Moreover, these ITS projects are consistent with the following goals and objectives from the overall COATS study effort (1).

- **Goal 1**: Improve the safety and security of the Northern California/ Southern Oregon Region rural transportation system users.

- **<u>Objective 1.1</u>**: Provide sustainable traveler information systems that collect and disseminate credible, accurate "real-time" information.
- **<u>Objective 1.2</u>**: Provide systems that advise regional transportation system users of slow-moving vehicles, obstructions and road and weather conditions.
- **<u>Objective 1.3</u>**: Provide systems that advise motorists from outside the region of alignment and speed conditions, tourist attractions, services, construction, weather, and the ability to request assistance.
- **<u>Objective 3.2</u>**: Provide automated notification of conditions that may impact operations and maintenance of regional roadways to improve resource management and allocation.

This evaluation sought to address whether the deployed wind warning systems met their design goals. Specifically, the evaluation intended to answer the following questions:

- Have these systems contributed to a safety improvement?
- Are motorists responding to the information presented to them?
- Does the system expedite the dissemination of the information? What are the other benefits that accrued due to this system?
- What are the strengths and weaknesses of each system?

The last question would have focused on a comparison of the system concepts used in Oregon, where a static sign is used, versus the proposed concept for California which would employ CMS. Because the CMS are not currently providing automated warnings during high-wind conditions, this question was not answered.

Based on these goals, Table 2-4 summarizes the objectives, measures of effectiveness (MOEs) and data sources proposed for this evaluation.

Table 2-4: Goals, Objectives and Measures of Effectiveness

Goal	Objective	Potential Measures of Effectiveness	Data Source
Improve the safety and security of the region's rural transportation system	Improve the safety of high profile vehicles	▪ Crash frequency for high profile vehicles ▪ Crash severity for high profile vehicles	Crash Data
	Improve safety of lower profile vehicles	▪ Crash frequency for all vehicles ▪ Crash severity for all vehicles	Crash Data
Provide sustainable traveler information systems that collect and disseminate credible, accurate "real-time" information	Improve the motorist information on severe weather conditions	▪ System usage by motorists ▪ Awareness of system among motorists	Motorist Survey
	Improve motorist acceptance and perception	▪ Sign clarity ▪ Message credibility and reliability	Motorist Survey
Increase operational efficiency and productivity focusing on system providers	Improve staff operations efficiency	▪ Savings in personnel time ▪ Reduction in the time to post a message	Maintenance Logs
	System reliability	▪ Number of full system outages ▪ Number of partial system outages	Maintenance Logs
	Improving emergency response	▪ Information sharing	Kick Off

The following steps were used in this evaluation methodology.

2.2.1. Literature Review

A comprehensive literature review was conducted to identify any other applications of wind warning systems in other parts of the nation. This review also included relevant literature about systems that have been deployed or evaluated elsewhere in the country. In addition, an online survey of state DOTs was conducted to determine where other systems existed in the country. Comparable systems internationally were also researched. Among the factors to be examined include rationale for system deployment, thresholds for system activation (e.g. maximum wind speed, sustained wind velocity over a certain time period), role of human intervention in system operation, accuracy, reliability, and measured benefits and costs.

2.2.2. Site Review

The research team traveled to California and Oregon to visit all three AWWS locations. They reviewed all relevant documents to each AWWS deployment, including project justification documents, site drawings, and other supporting documents identified by the evaluation team.

During the site visit, the research team familiarized itself with the nature of each location, local wind characteristics, and the volume and mix of vehicle traffic.

2.2.3. Safety Analysis

This task analyzed crash data before and after system implementation at each location to determine whether the AWWS have been effective in improving safety by reducing crash frequency or severity. Since the fully automated wind warning systems have been in place for only one high wind season, it was expected to be difficult to make statistically valid conclusions regarding improvements in motorist safety. Therefore, in addition to this basic analysis, a set of hypotheses was developed through a review of related international literature on crash analysis, along with an analysis of national crash data provided through the U.S. Department of Transportation's Highway Safety Information System (HSIS). An exploratory analysis on the crash data from HSIS for California and Minnesota was completed to describe a typical "high wind crash".

2.2.4. Motorist Survey

The purpose of the motorist survey was to gauge the subjective responses of motorists to the wind warning systems. Motorists were surveyed to determine the perceived benefits and effectiveness of the system through the following MOEs.

- Traveler awareness of these systems
- Traveler perception of the usefulness of these systems
- Traveler perception of the reliability of the system

The first step in survey development was developing a data collection plan. This data collection plan identified the relevant population and desired sample size, recommended preferred methods of survey distribution, outlined key areas of inquiry in the survey, and addressed other areas needed to conduct the survey. It was determined to be necessary to target commercial vehicle operators because of their greater vulnerability to high-wind conditions. The survey was constructed with an attempt to measure how motorists would have responded or would have perceived the roadway without the system in place. The same survey instrument was used for both Oregon systems to allow for analysis across locations. For mailback survey forms, a cover letter was also developed. The survey responses were analyzed to document AWWS effectiveness from the perspective of the motorist. More details about the motorist survey methodology may be found in the data collection plan, provided as Appendix A.

2.2.5. Technology Assessment

The purpose of this task is to assess the reliability of technologies used in these wind warning systems. System reliability – the extent to which the system operates continuously with a minimum of maintenance, either scheduled or unscheduled – was established through reviews of activation records, and telephone interviews with the responsible maintenance staff.

Diagrams depicting Theory of Operations (TOO) were developed to understand the physical architecture and the communication between system components. The reliability of the system was assessed by comparing the wind speeds measured at a nearby location to the system and the activation records of the system. This involved contact with responsible maintenance people and a review of all available records that document maintenance history with each site.

2.2.6. Operations Assessment

The installation of the automated wind warning systems was expected to result in savings in labor hours and a reduction in the time to get information to motorists. The objectives of this task were to identify and assess the system's operational benefits, and to validate the algorithm in the controller of the system. One potential benefit of these systems is the savings in personnel times and the reduction in exposure and risk for maintenance staff traveling between various sites. These savings will be documented by analyzing the available pre- and post-implementation data on operations. To supplement the findings on the operational savings, surveys of corresponding maintenance staff will be performed to record their perception.

To validate the system algorithm, the threshold wind speeds used to automatically activate and deactivate these systems were obtained from the corresponding staff and reviewed. These threshold speeds were compared with the critical wind speeds that have been determined to affect driver safety in the available literature.

In addition, the Yaquina Bay Bridge system was expected to have the capability to archive data on the system status (i.e. time intervals at which the system was active). This data will be reviewed along with the archived data on wind speeds to evaluate system reliability.

2.2.7. Summary of Evaluation Plan

Six measures of effectiveness (MOE) were chosen as the focus of this evaluation:

1. Reduction in wind induced accident frequency and severity
2. Traveler awareness of these systems
3. Traveler perception of the usefulness of these systems
4. Traveler perception of the reliability of the system
5. System accuracy
6. Operational cost savings.

MOE 1 is measured through an analysis of crash data for the years 1997 -2003. MOEs 2 through 5 are reviewed in the motorist survey results. MOE 5 is also measured through the technology assessment. MOE 6 is quantified through the operational assessment.

3. HIGH WIND IMPACTS AND WARNING SYSTEMS

High winds across highways pose a safety threat to traveling public. Oregon and California have deployed three automated wind warning systems (AWWS) that warn drivers of high wind hazards before they enter the high winds area. In order to assist in this evaluation of these systems, the research team performed a comprehensive review of literature related to the following areas.

- Safety impacts of high cross winds on vehicles
- Critical cross wind speeds for different vehicle classes
- Evaluations of similar systems nationally and in other countries, including automated maintenance related systems and driver warning systems

3.1. Safety Impacts of High Cross Winds

High winds across highways can cause high-profile vehicles to overturn and make vehicle control difficult for passenger cars. Some of the noted difficulties caused by high cross winds are serious safety concerns. Perry and Symons (2) describe three types of effects of cross winds on vehicles:

- *direct interference* with a vehicle through the force of the wind, at a minimum making steering difficult but, with sufficient wind strength, overturning the vehicle or pushing it off the road or into the path of another vehicle;
- *obstruction* caused by blowing snow, sand or other material into the highway, blowing down trees, parts of buildings and other debris; and
- *indirect effects* such as causing build-up of snow, creating conditions for avalanches, danger to bridges, etc.

Perry and Symons noted that the forces exerted by wind are proportional to the square of the wind speed and to the area of the vehicles facing the wind direction. So, high-profile vehicles experience more force than lower profile vehicles. Stability of all vehicles in motion is a complex problem in dynamics because of the sideways overturning moment, oscillatory forces at the rear of the vehicle and turbulent nature of low-level airflow and the induced eddies by the traffic itself. The sudden gusts induced by the moving traffic may exacerbate the situation.

In their study, Perry and Symons found that overturning accidents were the most common type of wind-induced accidents. In one windstorm in Great Britain in 1990, 66 percent of accidents involved high-sided commercial vehicles or vans, while only 27 percent involved cars. At the interface between atmosphere and the ground surface, friction reduces the wind speeds and makes the air turbulent, showing itself in sharp fluctuations in wind speed and changes in wind direction. Added to all these hazards, the sharp transitions in velocity which occur at highway features like tunnels and bridges resulted in frequent risks to the stability of high-profile vehicles, caravans, RVs and motorcycles.

In response to high-wind conditions, the British Transport Commission developed two tiers of wind warnings: Tier 1, where wind gusts are in excess of 70 mph; and Tier 2, where wind gusts exceed 50 mph. Perry and Symons recommended the following countermeasures apart from roadway design related countermeasures.

- Fixed or permanent precautions. These include artificial windbreaks (e.g. slatted fences) which can achieve 50 percent reductions of wind speed.

- Information and warnings. Fixed signs may be valuable as warnings but tend to become ignored over time. Electric signs have the advantage that they need appear only when required, but may be subject to signal interruptions during power loss.

- Closure of roads to all or certain classes of vehicles. Certain bridges may be closed to all vehicles or to high-profile vehicles when high winds are detected.

Perry and Symons concluded that many wind-related accidents occurred due to a failure to foresee the possible consequences of conditions which themselves may have been accurately forecast. Therefore, they advocated continuous wind monitoring, preferably with automatic recording and warning devices, for operational purposes. This could be facilitated through broad scale installation of road weather information systems (RWIS).

Edwards (3) examined wind-related accidents in England and Wales between 1980 and 1990, with specific interest in identifying the effects of wind on accident occurrence. The proportion of time of recorded high winds over a given time period was compared to the percentage of total accidents occurring in high winds over that same period. The proportion of accidents occurring in high winds was almost double the percentage duration of high winds. Wind-related accidents were defined as accidents that were recorded as having occurred during high winds under one of three conditions: good weather, rain, and snow. The term “wind-related” was used because the coding of high winds on the police accident report form does not imply that the high winds were a cause of the accident, but that they were deemed to have been a contributing factor.

This study also attempted to demonstrate, using severity ratios, that the presence of high winds at the scene of an accident largely determines accident severity. The proportion of time high winds was recorded over a given time period was compared to the percentage of total accidents occurring in high winds over that same period. If high winds did not affect the likelihood of an accident occurring, then the proportion of accidents occurring in high winds would equal the proportion of time for which high winds were recorded. After working around small sample size issues, the findings were inconclusive regarding the effect of high winds on accident severity unlike other weather hazards, such as rain (where there is a decrease in accident severity) and fog (which results in an increase in the severity of an accident).

Baker and Reynolds (4) analyzed wind-induced accidents in Great Britain. The objective of this study was to determine which vehicles are most at risk during windy periods and the likely values of critical wind speeds through analysis of the data from a major storm in 1990. This study determined that the most common type of wind-induced accidents is overturning accidents, which accounted for 47 percent of the total. Course deviation accidents and accidents involving trees comprised 19 and 16 percent, respectively.

3.2. Critical Cross-Wind Speeds

The second area researched in the literature review, was the wind speeds that endanger traveling vehicles, especially high profile vehicles. The British Transport and Road Laboratory calculated the threshold wind speed for danger to road vehicles generally at 35 mph, gusting to 50 mph (2).

Baker and Reynolds (4) concluded that the maximum gust wind speed during the hour of each accident was generally above 45 mph for about 90 percent of all accidents. This study also suggested that the traffic movement may be restricted at wind gust speeds (over approximately 3 seconds duration) greater than 38 to 45 mph.

Schmidlin examined the behavior and the degree to which different vehicles offer protection to occupants during tornado winds and associated debris (5). This study was based on an assessment of parked vehicle behavior through field survey-based observation of vehicles three to ten days after tornados. About 35 percent of the vehicles were moved by the wind but there was no difference in the percent of vehicles moved among F1 (73-112 mph), F2 (113-157 mph) and F3 (158-206 mph) wind speed classes.

Parked vehicles may be moved by the winds at F1 speeds, but vehicle damage has not been observed from these wind-induced movements even at F3 speeds. In rare cases, local wind patterns around a home may be sufficient to tip a vehicle even if house damage indicates a wind speed less than 112 mph (F1), but only 15 percent of vehicles tipped at houses where damage indicated winds in the F3 range.

Occupants were likely to have been seriously injured in 39 of the 180 vehicles (22 percent). There was a significant difference ($p < 0.005$) between the percentage of occupants likely to have been seriously injured at sites with F1 and F2 damage (16 percent) and the percentage of occupants likely to have been seriously injured at sites with F3 damage (39 percent). The difference was largely due to greater battering and penetration by debris into the passenger compartment of the vehicles exposed at sites with F3 damage.

It should be noted that this study examined only the behavior of parked vehicles. It is known that the static friction is higher than the kinetic friction, so tornado-level speeds would not be required to cause instability in a moving vehicle. It should also be noted that parked vehicles are less prone to overturning than moving vehicles as they experience aerodynamic forces. So, the actual wind speed thresholds for moving vehicles are less than the thresholds for parked vehicles determined by this study.

Cooper (6) investigated the effects of high cross winds on trains. This study estimated overturning wind speeds for vehicles (i.e. rail cars) based on simple static and steady aerodynamic forces. Saiidi (7) examined trigger wind velocities that can cause vehicle instability. The objective of this study was to determine the critical wind velocity and incidence angle that would overturn different vehicle types. A variety of road surface conditions, vehicle types and profiles, vehicle speeds, and vehicle loads are considered to identify the most critical condition through common models used in engineering mechanics. This study concluded that the most critical wind angle is when the wind direction is perpendicular to the sides of the vehicle or, in effect, when the wind is perpendicular to the road axis. Due to their low profiles and generally aerodynamic designs, automobiles are unlikely to reach a critical condition in terms of stability under typical wind loads. Both the modes of instability under windy conditions (i.e. overturning and sliding) were researched. The sliding mode is more likely under wet (i.e. snow/ice covered) pavement conditions. The empty weight of the vehicles was found to be the critical scenario (low resistance) for both the overturning and sliding modes. The following three tables (Table 3-1, Table 3-2, and Table 3-3) show the critical wind speeds for Trucks, RVs with 2 ft. wheel diameter, and RVs with 3 ft. wheel diameter respectively.

Table 3-1: Critical Wind Speeds for Trucks and Trailers

Vehicle	Weight (lbs.)	Wheel Base (ft.)	Length (ft.)	Vehicle Height (ft.)	Wheel Diameter (ft.)	Overturn Wind Speed (mph)	Slide Wind Speed (mph)
Single Truck	15,000	6	40	14	4	59	31
Twin Combination	30,000	6	70	14	4	63	33
Semi - trailer	30,000	6	53	14	4	73	38
Single Trailer	15,000	3	45	14	4	40	29

(Source: 7)

Table 3-2: Critical Wind Speeds for Recreational Vehicles with 2-ft. Wheel Diameter

Vehicle	Weight (lbs.)	Wheel Base (ft.)	Length (ft.)	Vehicle Height (ft.)	Wheel Diameter (ft.)	Overturn Wind Speed (mph)	Slide Wind Speed (mph)
Motor Homes	9,000	6	26	10	2	79	34
	10,000	6	30	12	2	65	30
	12,000	6	34	12	2	67	31
	14,000	6	36	12	2	70	33
	15,600	6	43	11	2	74	33
	22,000	6	40	12	2	83	39
	27,000	6	45	13	2	80	39
Camping Vans	4,500	6	17	7	2	100	36
	7,000	6	20	10	2	80	34
Travel Trailers	1,800	6	27.5	9	2	38	16
	2,200	6	18	9	2	52	21
	3,300	6	27.5	9	2	52	21
	4,000	6	28	10	2	51	22
Fifth-Wheel Trailers	4,500	3.5	34	10.2	2	37	21
	5,000	3.5	36	10.5	2	37	21
	6,000	3.5	31	11	2	41	24
	8,000	3.5	36	12	2	40	25

(Source: 7)

Table 3-3: Critical Wind Speeds for Recreational Vehicles with 3-ft. Wheel Diameter

Vehicle	Empty Weight (lbs.)	Wheel Base (ft.)	Length (ft.)	Vehicle Height (ft.)	Wheel Diameter (ft.)	Overturning Wind Speed (mph)	Sliding Wind Speed (mph)
Motor Homes	9,000	6	26	10	3	80	35
	10,000	6	30	12	3	65	31
	12,000	6	34	12	3	67	32
	14,000	6	36	12	3	70	33
	15,600	6	43	11	3	74	34
	22,000	6	40	12	3	84	40
	27,000	6	45	13	3	81	40
Camping Vans	4,500	6	17	7	3	101	38
	7,000	6	20	10	3	80	35
Travel Trailers	1,800	6	27.5	9	3	39	16
	2,200	6	18	9	3	53	22
	3,300	6	27.5	9	3	52	22
	4,000	6	28	10	3	51	22
Fifth-Wheel Trailers	4,500	3.5	34	10.2	3	37	21
	5,000	3.5	36	10.5	3	37	22
	6,000	3.5	31	11	3	41	25
	8,000	3.5	36	12	3	41	25

(Source: 7)

It can be seen from Table 3-2 and Table 3-3 that the critical wind speeds to make the vehicles slide are lower than the critical wind speeds for causing vehicles to overturn. It should also be noted that most types of vehicles may start to slide at a wind speed of 35 mph.

3.3. Evaluations of Similar Systems

The last part of the literature review effort was to identify evaluations of similar systems (i.e. automated active systems warning about weather hazards). An average commercial vehicle incident costs $62,613 (in 2003 U.S. dollars), with interstate highway closures due to these crashes causing losses of millions of dollars (8). The business practice of "just in time" delivery of goods and rolling warehouses requires that restrictions and closures of interstates be eliminated or kept to a minimum.

Meena (9) studied countermeasures for truck incidents resulting from severe weather conditions on remote interstate highways. This paper researched countermeasures of categories including decision-making, restrictions and advisories, traffic and road features, information systems, surveillance and detection, and automated systems. All surveyed states reported using an up-to-date web page for real-time road and travel information, while automated systems were least used. Length restrictions and dynamic or changeable message signs were reported to be the most effective tools to reduce truck incidents.

This study noted that remotely-activated beacons may be used to provide timely information about road closures, chain requirements, and highway advisory radio broadcasts. The study recommended that advance signs with flashing beacons be placed approximately one mile prior to the outer edge of the radio broadcast range. This study emphasized that keeping driver confidence in information systems is critical to reaching their desired effectiveness.

This survey of state DOT personnel in the study identified the current practices to counter commercial vehicle incidents through restrictions and advisories. The results are summarized in Table 2-1 (8). Additional or larger warning signs were reported in use by nine respondents from eight different states. The average effectiveness of 3.4 was reported as slightly higher than somewhat effective.

Table 3-4: Countermeasures and their Effectiveness

Countermeasures	Average Reported Effectiveness (5 = maximum, 1 =-minimum)	Number of States Using the Countermeasure
Reduced Winter Speed Limits	5	1
Variable Speed Limits	5	1
Length Restrictions	4.8	7
Reduced Truck Speed Limits	4	4
Advisory Speeds for Trucks	4	4
Closures to Trucks Only	3.4	4
Lane Restrictions for Trucks	2.8	4

(Source: 8)

Table 3-5 shows the use and perceived effectiveness of information system based countermeasures in the states surveyed for this study. This table, in comparison with Table 3-4, shows that information system-based countermeasures are used more frequently and the perceived effectiveness is high. As it can be noted in Table 3-5, the two most effective countermeasures for commercial vehicle incidents were found to be CMS at diversion points and CMS near problem areas. Thus, it can be inferred that providing timely automated wind warning messages through CMS or flashing beacons at diversion points before they get into the high wind area will be perceived to be most beneficial by the road users.

Table 3-5: Information System-Based Countermeasures and their Effectiveness

Countermeasure	Average Reported Effectiveness (5 = maximum, 1 = minimum)	Number of States that use this Countermeasure
CMS / VMS at Diversion Points	4.7	6
CMS / VMS Near Problem Areas	4.5	6
Signs With Flashing Beacons	4.3	6
Webpage with Road and Weather Restrictions	4	9
Highway Advisory Radio (HAR)	3.9	8
511 or Other Toll Free Number for Road Conditions	3.4	7
Kiosks in weigh Stations, Rest Areas or Truck Stops	3.4	3

(Source: 8)

Amiri (10) studied the potential reduction in delays and the number of accidents by automating road closure gates in Minnesota. This report documents potential savings attributed to a reduction in delays experienced by both passenger vehicles and heavy trucks. Based on AADT recorded by the Minnesota Department of Transportation (Mn/DOT) in District 7, a three-hour delay on Interstate 90 can cost from $36,400 to $78,000, depending on traffic volumes. With approximately 80 snow- and ice-related crashes per year on the gated segment, a five percent reduction in accidents annually would lead to an estimated annual savings of $31,600. The costs of the gates were $3,700 per gate and Mn/DOT installed 43 gates in this section. The data used in this study was from a severe snowstorm that struck District 7 in November 1998 that provided a good case study to compare costs for clearing a section of I-90 (with gates) and US Route 75 (without gates). Based on Mn/DOT's Operations Management System Reports from the day that both roads were cleared to bare pavement (95 percent clear), the following comparisons were made.

- Plows made four passes before Interstate 90 was 95 percent clear and opened, while 10 passes were made on US Route 75 before it was 95 percent clear.
- For Interstate 90, approximately $20 in labor and materials was expanded per lane-mile, while approximately $24 was expended per lane-mile for US Route 75.
- Interstate 90 was cleared to bare pavement (95 percent clear) approximately four hours sooner than Highway 75 was cleared to bare pavement (95 percent clear)

Amiri concluded that these automated gates improved the safety of the travelers and the traffic operations during winter storms.

Carson and Mannering (11) investigated the effect of ice warning signs on ice-accident frequencies and severities. This research evaluated the effectiveness of ice warning signs in reducing accident frequency and accident severity in Washington State. The findings of this study could not statistically conclude that installing ice warning signs influenced the accident rates at any location. However, this study identified significant spatial, temporal, traffic, roadway and accident characteristics that influenced ice-accident frequency and severity. These characteristics could be used for better placement of ice warning signs and improvements in roadway and roadside design that can reduce the frequency and severity of ice-related accidents.

Hauer (12) concludes that the hallmark of an enlightened road safety delivery program is balanced attention to road users, vehicles and the road. Road design can reduce the incidence of human error, reduce the chance of a human error to end up as a crash, and reduce the severity of the consequences of crashes that are initiated by human error. The AWWS evaluated here attempt to reduce the human errors through prompt and adequate warning. Altering the road design at the AWWS locations is not feasible as the US Route 101 runs right along the Pacific coast and has limited room to expand, in addition to being a scenic highway that provides access to numerous state parks.

3.4. Current Practices in High Wind Warnings

State departments of transportation across the nation have been using various types of warning signs for road hazards including weather-related ones. With the recent advent of ITS, there have been efforts to automate some of these warning systems. Because there are relatively few evaluations of these ITS systems, a nationwide survey of state DOTs was conducted to assess the current use of automated warning systems of high winds in March 2003. An online survey was developed for this purpose. A link to this online survey web page was emailed to the traffic operations staff at 43 states[1]. Nineteen of these forty three states responded to the online survey. A summary of these responses is provided in Table 3-6. Montana, Nevada, Pennsylvania, Utah and Washington currently use either automated or manually operated active wind warning systems among the states that responded. Of these, Nevada's system is the only one which is fully automated; it uses a RWIS integrated with a dynamic message sign to warn motorists. Wisconsin planned to complete the installation of an RWIS-based wind warning system in 2004.

More details on the wind warning systems used in the states that responded to this survey are presented in Appendix B.

[1] These states listed an e-mail address at their traffic operations or ITS division on their web sites.

Table 3-6: Summary of DOT Staff Responses on Wind Warnings

	State	Use of WWS	Presence of Prevailing High winds	Comments
1	Montana	Yes	Yes	I 90, Automated, VMS/RWIS
2	Nevada	Yes	Yes	VMS/RWIS
3	Pennsylvania	Yes	Yes	Static signs with flashing beacons, to be upgraded to automated VMS messaging. White out caused a 30-car crash with 4 fatalities.
4	Tennessee	Yes	No	Static Signs
5	Utah	Yes	No	No automated wind warning. TOC receives wind alarms from SSI's Scan Sentry software.
6	Washington	Yes	Yes	4 Locations. SR 520, I-90, SR 104 and SR 16 (Wind Socks and Camera)
7	Wisconsin	Yes	Yes	Planned to be completed in 2004. RWIS/VMS
8	Alabama	No	No	
9	Arkansas	No	Yes	
10	Colorado	No	Yes	Highway Patrol /Maintenance requests
11	Kansas	No	Yes	Only Wind Socks
12	Kentucky	No	No	
13	Massachusetts	No	No	
14	Missouri	No	No	
15	New Jersey	No	No	
16	New Mexico	No	Yes	
17	North Dakota	No	Yes	Copy of the survey findings
18	South Dakota	No	No	
19	West Virginia	No	Yes	Locations with very low ADTs

4. SAFETY ANALYSIS

These wind warning systems are aimed at warning drivers of high wind conditions more promptly and efficiently, along with improving the safety of travelers and the maintenance personnel. Safety-related measures of effectiveness (MOEs) include measures such as the reduction in crash frequency, reduction in crash severity, reduction in truck involvement in crashes, and reduction in wind-influenced crashes.

This type of crash analysis is most trustworthy when there are clear demarcations between before and after a safety improvement is made. In this case, however, it is more difficult.

ODOT was warning motorists of high winds across highways even before these systems were implemented, by closing roadways when the average wind speeds sustain above 35 mph. Moreover, Oregon's crash reporting form does not provide a field for the investigator to document "wind" as a contributing factor. Thus, the crash data does not identify accidents directly influenced by high winds. So, there were not any direct ways of measuring the change in wind-influenced crashes in a "before" and "after" analysis.

A comparison between crash rates before and after system implementation could indicate whether the wind warning systems have been effective in improving overall safety of drivers. Since these systems have been in place for only one high wind season, the differences in the crash rates before and after system automation could not be measured in a statistically robust fashion, as the variations in crash rates could just be random variations. Any change in crash rate could also not be directly attributed to the AWWS implementation, as the number and the duration of wind events could vary from year to year. Also, there could have been other safety improvements that could have contributed to lesser number of accidents.

Therefore, to provide a context for understanding the crash data, this analysis identified project milepost limits within which the system's impact was expected, and developing hypotheses to be tested in the crash data analysis. A set of hypotheses was developed through a review of related international literature on crash analysis, along with an analysis of national crash data provided through the U.S. Department of Transportation's Highway Safety Information System (HSIS). An exploratory analysis on the crash data from HSIS for California and Minnesota was completed to describe a typical "high wind crash". (These findings are discussed in greater detail in Technical Memorandum 3 [13].) These findings then were transferred to the Oregon locations to identify trends.

4.1. Methodology and Data

The Federal Highway Administration (FHWA) has developed HSIS as a database for use in safety analysis studies. The database includes crash data from nine states. Of the nine states, Minnesota and California were selected because the crash data from these states had indications of when high wind conditions were present and had significant amount of rural highways. To make data requirements more manageable, this analysis used HSIS data from California and Minnesota for years between 1997 and 1999. The HSIS data set consists of three interrelated subsets: accident, vehicle and occupant. For this analysis, the focus was on the accident and vehicle components of the data set.

Crash records for both states allow for coding of wind as a causative factor or weather condition during vehicle crashes. However, the analysis of wind-influenced vehicle crashes is difficult. In both states, wind is reported as one of many values for "weather" governing a particular accident. In Minnesota, for example, the weather field includes other values such as snow or blowing snow. Where more than one of the values is present (for example, it is both snowing and windy), the field investigator would be limited to recording one value. Therefore, the number of accidents in which wind is a causative factor would be underestimated by including only those incidents where wind is listed as the dominant weather condition.

In California's data set, wind is listed not only as a value for weather (in the accident data set), but also as a causative factor (in the vehicle data set). In some cases, investigators would record wind in both data fields, but there were many cases where it was recorded in one and not the other. For the analysis presented in this paper, a crash was counted as wind-influenced even if one of the fields (i.e. causative factor or weather) was entered as "wind". While this would ideally develop a more comprehensive set of wind-influenced crashes, there is also the subjectivity in the process that the interpretation of windy conditions is left to the investigator. A number of questions (e.g. is 30 mph a reasonable level to describe as windy?) are not answered in the standard accident reporting forms. Therefore, while this analysis is quantitative in nature, caution is urged in extrapolating the findings to estimate the safety benefits of measures that may mitigate wind-related crashes.

4.2. Extent of Wind-Influenced Crashes

In this section, the relative frequency and variation (temporal and geographic) of wind-influenced crashes is examined.

4.2.1. Frequency

Even considering potential underreporting, wind-influenced crashes are relatively infrequent. In Minnesota, 0.11 percent (244 of 228,273 crashes) of the total number of crashes was recorded as wind-influenced. The percentage was higher in California – 0.64 percent (3,228 of 501,901). The difference may be attributable to differences in reporting, but it could also be related to California's mountainous terrain, or possibly more frequent cross-winds on California roadways.

4.2.2. Temporal

To look at temporal characteristics of wind-influenced crashes, an index was set up:

$$index_i = 100 \times \frac{\sum_{i=1}^{N} n_i}{\sum_{i=1}^{N} w_i} \times \frac{w_i}{n_i}$$

where w_i = the number of wind-influenced accidents in the i^{th} time period
n_i = the number of non-wind accidents in the i^{th} time period
i = the time period of interest (e.g. month of October or 12th hour of the day)
N = the number of time periods examined (e.g. 12 months for a year, 24 hours for a day)

An index value of 100 indicates no temporal abnormalities, whereas values greater than or less than 100 indicate higher-than-expected or lower-than-expected frequencies of wind-influenced crashes, respectively.

Figure 4-1 shows index values for different months of the year and Figure 4-2 shows index values for different hours of the day. As can be seen, wind-influenced crashes are more likely to occur during the winter and early spring months in both states. In Minnesota, there appears to be a trend toward increasing frequency of wind-influenced crashes during the late afternoon. There is no similar trend in the California crash data. It is suspected that time-of-day wind-influenced crash trends may be masked by the higher proportion of urban-area commute trips that occur in California compared to Minnesota.

Figure 4-1: Relative Frequency of Wind Influenced Crashes by Month

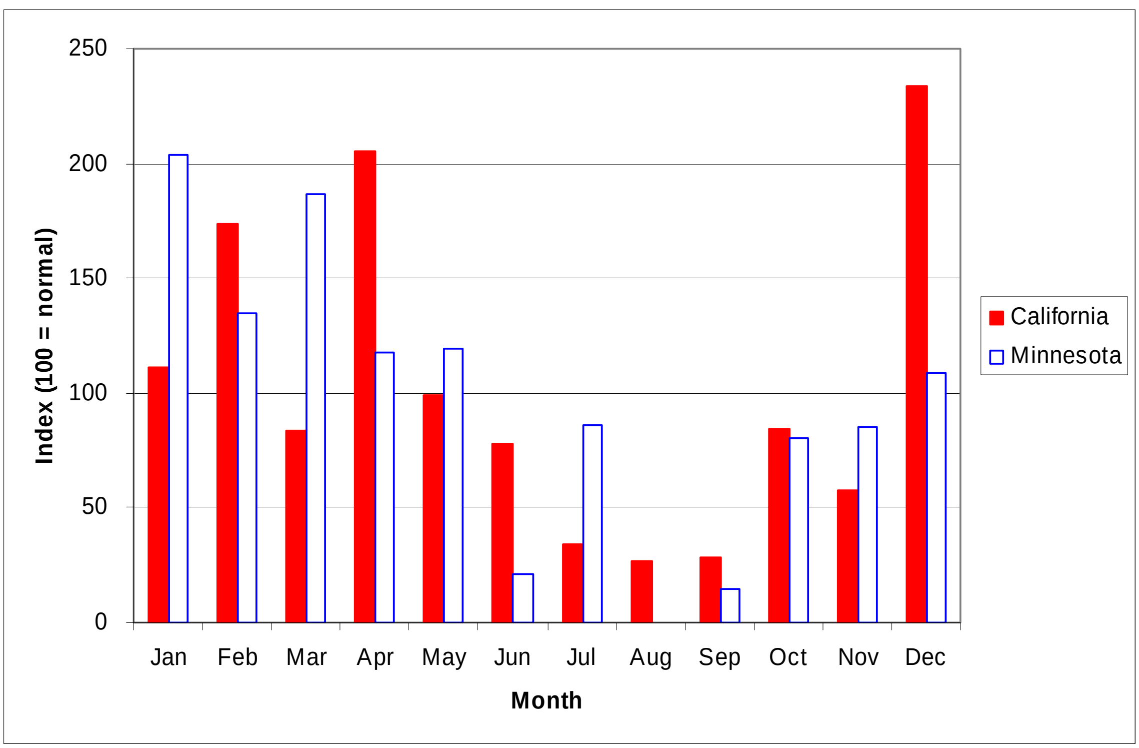
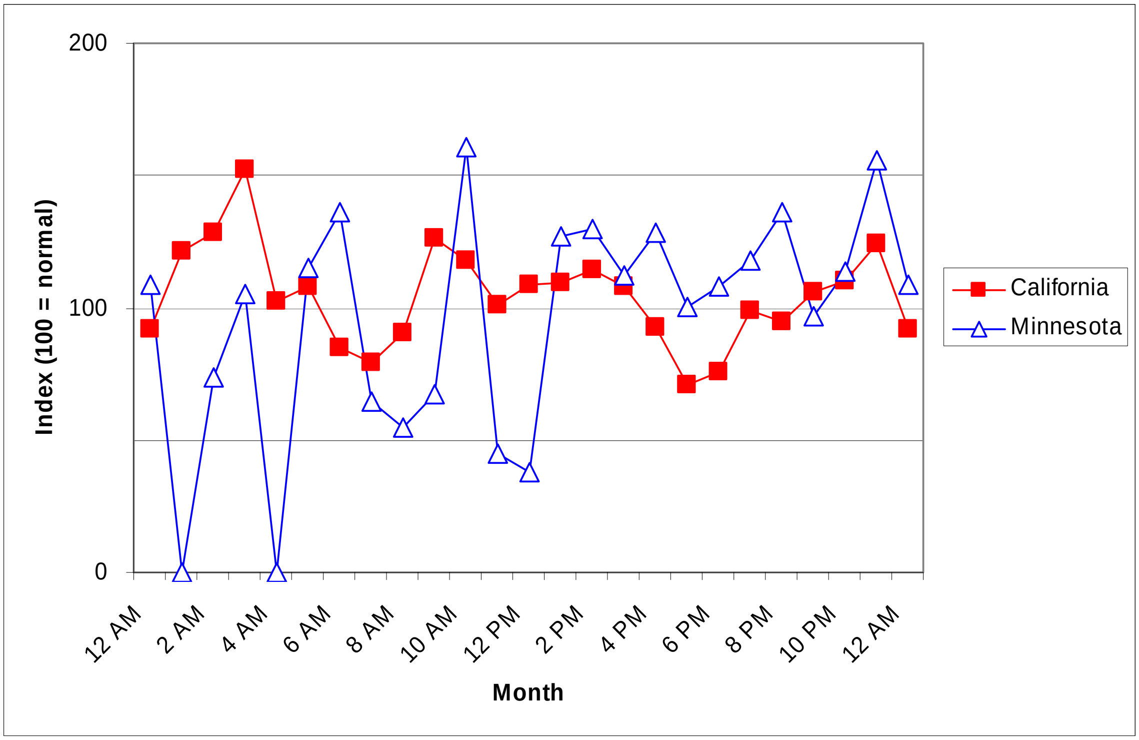


Figure 4-2: Relative Frequency of Wind Influenced Crashes by Time of Day



4.2.3. Geographical

To examine the geographic spread of wind-influenced crashes in each state, the locations of crashes were examined by county and highway, whether an area was rural or urban, and the type of highway facility.

By County and Highway

Wind-influenced crashes tend to be relatively localized phenomena. To demonstrate this, crashes were classified by county and highway to determine trends. In California, there are clear differences across counties in the proportion of crashes that were influenced by wind. While only 0.64 percent of crashes statewide were classified as wind-influenced, in three counties – Imperial, Inyo and Mono, all of which are located in the eastern part of the state – wind was cited as an influence in crashes at least five times more frequently. Since highway mileposts in California are consecutively numbered only within each county, the data permits ready analysis of trends on the entirety of a particular highway within a given county. At this level, there are 521 county-highway segments within the state.

The percentage of wind-influenced crashes for each county-highway segment was calculated, and ten percent of the segments had percentages of 3.1 percent or greater. Of these segments, six each were located in Imperial, Riverside and San Bernardino counties (all of which are eastern counties) while 35 of California's 58 counties had no segments in the 10 percent highest proportion of wind crashes, again suggesting a geographic concentration.

Data was also analyzed by one-mile segments on each highway. Of these 13,821 segments, 85 percent of these segments reported no wind-influenced crashes, and another ten percent had only one wind-influenced crash over a three-year period. There were 182 segments which had more than one wind-influenced crash, and where at least 10 percent of crashes were wind-influenced.

In Minnesota, the relative infrequency of wind-influenced crashes makes the interpretation of statistics regarding localized concentration of crashes challenging. For example, three of the state's 87 counties have a percentage of wind-influenced crashes at least ten times the state's average frequency of wind-influenced crashes of 0.11 percent. However, these three counties combined for a total of only 12 wind-influenced crashes over the analysis period. Only four Minnesota counties reported more than 10 wind-influenced crashes over a three-year period, compared to 40 counties in California. An analysis of crashes by highway and milepost shows similar difficulties.

Rural Vs. Urban

Wind-influenced crashes were also analyzed by whether they occurred primarily in urban or rural areas. The California data set includes two designations which may indicate whether a crash occurred in an urban or a rural area – whether the crash occurred in an incorporated area, and the roadway classification of the highway where the crash occurred. Approximately 57 percent of wind-influenced crashes in California occurred in unincorporated areas, while only 29 percent of non-wind crashes occurred in these areas. Forty-eight percent of wind-influenced crashes occurred on highway segments classified as rural, compared to 18 percent of non-wind crashes.

Minnesota's data set provides two similar designations in each accident record to help classify crashes as rural or urban. Eighty-one percent of the wind-influenced crashes in Minnesota occurred in unincorporated areas or towns with a population of less than 1,000, as compared to 30 percent of non-wind crashes. Eighty-two percent of wind-influenced crashes occurred on highway segments classified as rural, compared to 29 percent of non-wind crashes.

While the concentration of wind-related crashes in rural areas is clear, the reasons for this are not self-evident and do not necessarily have direct traffic safety applications. For example, urbanization may tend to occur in areas with less wind. Nonetheless, it appears that wind-influenced crashes are a greater concern in rural areas than in urban areas.

Type of Facility

Table 4-1 shows the percentage of wind-influenced and non-wind crashes which occurred on different highway types in each state. In both states, wind-influenced crashes are relatively more frequent on two-lane roads; however, there are not any clear trends regarding freeways or multi-lane facilities. With two-lane roadways typically found in more rural areas, there may be some correlation between this finding and the previous observation that wind-influenced crashes are more frequently a rural phenomenon.

Table 4-1: Percentage of Crashes by Highway Type

	California		Minnesota	
Highway Type	Wind	Non-Wind	Wind	Non-Wind
Other	1.7%	1.0%	1.3%	3.4%
Freeway, 4 or more lanes	61.7%	69.7%	28.2%	17.5%
Freeway, less than 4 lanes	1.1%	0.4%	0.0%	0.1%
Multi-lane divided, non-freeway	15.9%	13.4%	13.7%	19.9%
Multi-lane undivided, non-freeway	3.8%	3.5%	1.3%	12.0%
Two-lane roads	15.8%	12.0%	55.6%	47.1%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**

4.3. A “Typical” Wind-Influenced Crash

As mentioned earlier, wind-influenced crashes may be underreported due to the constraints of data collection instruments used during crash investigations. Though the HSIS data may not always indicate when high winds were present or were a major causative factor in a crash, they may be useful to compare a typical wind-influenced crash with a crash that occurs when high winds are not present. The “typical” wind-influenced crash will be classified according to the number and type of vehicles involved, the type of collision, the severity, and road surface conditions.

4.3.1. Number of Vehicles and Types of Vehicles

In both states, the average wind-influenced crash involves fewer vehicles than a non-wind-influenced crash. In California, the average number of vehicles involved in a wind-related crash was 1.69 compared to 1.99 for non-wind crashes; in Minnesota, the comparison numbers are 1.36 and 1.86, respectively. In Minnesota, 69.3 percent of wind-influenced crashes involved only one vehicle, compared to 24.7 percent of non-wind-influenced crashes. A parallel analysis for California showed that 42.7 percent of wind-influenced crashes involved one vehicle, versus 23.6 percent of non-wind-influenced crashes.

Passenger cars, pickup trucks and sport utility vehicles are the most commonly involved vehicles in crashes, irrespective of whether wind was a causative factor. However, wind-influenced crashes have a higher likelihood of trucks being involved than non-wind influenced crashes. In Minnesota, 28.3 percent of wind-influenced involved at least one truck, compared to 6.3 percent of non-wind-influenced crashes. In California, 22.2 percent of wind-influenced crashes involved at least one truck, compared to 12.7 percent of non-wind-influenced crashes.

The observation that trucks are more commonly involved in wind-influenced crashes is especially evident when looking at one-vehicle crashes. In Minnesota, only 3.5 percent of non-wind-influenced one-vehicle crashes involved a truck, compared to 25.4 percent of wind-influenced one-vehicle crashes. In California, only 6.0 percent of non-wind-influenced one-vehicle crashes involved a truck, compared to 17.6 percent of wind-influenced one-vehicle crashes.

4.3.2. Type of Collision

Each state has different methods of describing collisions. In Minnesota, collision type is described in two data fields: one which diagrammatically describes the crash (for example, sideswipe), and another which characterizes the participating actors in the crash (for example, crash with vehicle). In California, these characteristics are essentially combined.

Minnesota data showed that the predominant type of wind-influenced crash was run-off-the-road crashes, with these comprising 45.9 percent of all wind-influenced crashes. In contrast, only 14.8 of non-wind-influenced crashes were described as run-off-the-road. Hit object collisions are also relatively more common in wind-influenced crashes than in non-wind-influenced crashes. In addition, 38.5 percent of wind-influenced crashes were described as vehicle overturn crashes, compared to only 6.1 percent of non-wind-influenced crashes. As shown in Table 4-2, the observation that hit object and overturn crashes are more frequent in wind-influenced crashes compared to non-influenced crashes holds true in California as well.

Table 4-2: Percentage of Crash by Type in California

Collision Type	Wind	Non-Wind
Auto/Pedestrian	0.6%	0.8%
Broadside	9.9%	9.6%
Head-on	1.6%	1.5%
Hit Object	30.2%	22.6%
Not Stated	0.0%	0.0%
Other	9.1%	4.1%
Overturn	12.0%	3.0%
Rear End	24.4%	42.9%
Sideswipe	12.1%	15.5%
Total	**100.0%**	**100.0%**

4.3.3. Crash Severity

Table 4-3 shows how the severity of wind-influenced crashes compares with non-wind-influenced crashes. In both states, wind-influenced crashes are more likely to result in fatalities or injuries than non-wind-influenced crashes. This would appear to be a relationship that is causative, not correlative, in nature. Crash types that tend to have more harmful outcomes (for example, overturned vehicles) are more likely to be caused by wind than crashes with less harmful outcomes (e.g. rear end collisions). A chi-square analysis showed that the relative severity of wind-influenced versus non-wind crashes of the same crash type was different for each crash type, although ambiguous in the direction of difference.

Table 4-3: Severity of Wind-Influenced and Non-Wind Crashes

	California		Minnesota	
Incident Severity	Wind	Non-Wind	Wind	Non-Wind
Fatal	1.4%	0.8%	1.2%	0.7%
Incapacitating Injury	3.5%	2.0%	3.3%	3.3%
Non-incapacitating Injury	15.1%	12.7%	17.6%	13.5%
Possible Injury	15.7%	19.3%	17.2%	19.3%
Property Damage Only	64.3%	65.1%	60.7%	63.2%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**

4.3.4. Road Surface

In both states, a higher percentage of wind-influenced crashes occurred on icy or snowy road surfaces than did non-wind-influenced crashes. In Minnesota, 46 percent of wind-influenced crashes occurred on icy or packed snow road surfaces compared to 12 percent of the same in non-wind conditions. In California, only 3.8 percent of wind-influenced crashes occurred on icy, snowy or slippery road surfaces, but this compared to 1.2 percent of non-wind-influenced crashes. This suggests wind may act as a compounding factor in lowering visibility or decreasing drivers' ability to control their vehicles.

Additional investigation into the interrelationship between road surface, crash severity and the presence of winds showed that wind-influenced crashes were generally more severe than non-wind-influenced crashes, controlling for the road surface present at the time of the crash. In other words, a wind-influenced crash appears to be more severe than a non-wind-influenced crash, whether the pavement is dry or not.

4.4. Summary of HSIS Safety Analysis

In the preceding analysis, there was a statistically significant difference between the typical characteristics of wind influenced crashes and the non-wind crashes. Chi-square tests were used to test the statistical significance of the difference in the distribution of accident type and vehicle type between wind-influenced and non-wind crashes. Z-tests were used for testing whether the average number of vehicles involved and the average number of trucks involved are statistically different between wind influenced and non wind crashes. Table 4-4 highlights the results of these tests of significance between wind-influenced and non-wind crashes. Table 4-5 summarizes the analysis of the characteristics of wind-influenced crashes. Table 4-6 depicts the "typical" characteristics of a wind influenced crash based on the number and type of vehicles involved, the type and severity of collision and road surface conditions during the crash.

Table 4-4: Summary of Test of Significance Results

Variables	California		Minnesota	
	Z / χ^2 Value	Pass / Fail at 5 % Sig.	Z / χ^2 Value	Pass or Fail at 5 % Sig.
Average Number of Vehicles Involved	-32.94	Fail	-20.13	Fail
Accident Type	1426.2	Fail	942.82	Fail
Vehicle Type Involved	1409.32	Fail	316.76	Fail
Average Number of Trucks Involved	14.05	Fail	-56.44	Fail

Table 4-5: Comparison of Typical Wind-Influenced and Non-Wind Crashes

Description	California		Minnesota	
	Wind	Non-Wind	Wind	Non-Wind
Number and Type of Vehicles				
Average number of vehicles involved	1.69	1.99	1.36	1.86
Percent of single vehicle crashes	42.7%	23.6%	69.3%	24.7%
Percent of crashes with at least one truck	22.2%	12.7%	28.3%	6.3%
Percent of truck involvement in single vehicle crashes	17.6%	6.0%	25.4%	3.5%
Type of Collision				
Percent of run-off-the-road (ROR) crashes	-	-	45.9%	14.8%
Percent of vehicle overturn crashes	12.0%	3.0%	38.5%	6.1%
Percent of hit-object crashes	20.2%	22.6%	-	-
Road Surface				
Percent of crashes on icy/snowy/slippery roads	3.8%	1.2%	46.3%	12.2%

Table 4-6: List of "Typical" Wind Crash Characteristics

Descriptive Variable	Predominant Value	2nd Predominant Value
Number of Vehicles Involved	Two Vehicles	Single Vehicle
Type of Vehicle Involved	Passenger Car / Pick Up / SUV	Trucks
Type of Collision	Run-off-the-road (ROR) Crashes / Hit Object	Other / Unknown / Rear End
Severity of Collision	Property Damage Only (PDO) Crashes	Complaint of Pain / Non-Incapacitating Injury
Road Surface Condition	Inconclusive	Inconclusive

4.5. Review of Oregon Crash Data

Crash frequency and crash rates for the two AWWS locations in Oregon are shown in Table 4-7 and Table 4-8. Crash data for years between 1997 and 2003 were used for this analysis. It should be noted that the two systems were fully or partially automated by January 2004; before this, both systems had the capability of being manually activated from a remote location. Historically, there have always been warnings and road closures provided to enhance the safety of the traveling public during high wind conditions. Therefore, a before-after safety benefit assessment was not performed as part of this study. However, with the AWWS providing more reliable and prompt wind warnings, fewer vehicles will be exposed to high wind events, which consequently should reduce crash risk.

Table 4-7: Wind Season Crash Rate (South Coast System)

	Number of Crashes		Crash Rate (per million VMT)	
Year	Wind Season	Total	Wind Season	Total
1997	10	21	1.20	0.83
1998	3	12	0.36	0.46
1999	3	10	0.35	0.37
2000	3	12	0.37	0.44
2001	6	21	0.68	0.74
2002	6	14	0.68	0.48
2003	10	19	0.99	0.66
2004	5	17	0.55	0.58

Notes:
Includes crashes on US Route 101 from Mileposts 300.10 to 327.51.
Wind Season includes months of January, February, March, November, and December.
In 2004, 20 percent less crashes were reported due to changes in the DMV reporting requirements in Oregon

Table 4-8: Wind Season Crash Rate (Yaquina Bay Bridge)

Year	Number of Crashes		Crash Rate (per million VMT)	
	Wind Season	Total	Wind Season	Total
1997	6	8	3.33	1.59
1998	4	8	2.07	1.46
1999	3	5	1.54	0.93
2000	2	3	0.96	0.94
2001	1	1	0.53	0.18
2002	0	0	0.00	0.00
2003	1	1	0.48	0.18
2004	1	1	0.55	0.35

Notes:
Includes crashes on US Route 101 from Mileposts 141.27 to 142.08.
Wind Season includes months of January, February, March, November, and December.
In 2004, 20 percent less crashes were reported due to changes in DMV reporting requirements in Oregon

The crash rates during the high wind months – November through March – were consistently higher for the Yaquina Bay Bridge system and usually higher for the South Coast location than the annual rates at these locations. The months of high wind season are also the winter months at these locations and a higher crash rate can not solely be attributed to high cross winds. Moreover, because the Oregon crash reporting form does not list "high winds" as a contributing factor to a crash, it is uncertain how many of these crashes were caused by high winds. A before-after comparison of crash rates will only have the after scenario with just one year data. So, the comparison was not done.

5. MOTORIST SURVEY

A motorist survey was conducted to evaluate the AWWS regarding awareness of these systems and their perceived usefulness. This chapter presents the survey instrument design and distribution methods used, demographic and travel characteristics of survey respondents, motorist perception of high winds and high wind forecast, awareness of AWWS and assessment of their functionality. More details on survey responses are documented in Technical Memorandum 1 (16).

5.1. Survey Design

The specific objectives of the motorist surveys were to assess user perception of high cross winds as a safety hazard, user awareness of the warning systems at these locations, user reaction to wind warning messages, and the accuracy and usefulness of the AWWS. The survey solicited the following types of information:

- Traveler characteristics
- Traveler perception of high winds as a hazard
- Traveler awareness of AWWS
- System functionality
- Demographic information

Three types of response options were used throughout the surveys: multiple-choice, ordinal ratings and open-ended questions. For the rated responses (ordinal ratings), survey respondents were instructed to select values from 1 to 5 that they felt best represented their behavior or opinion regarding a particular topic. The ordinal nature of such a scale allows conclusions to be drawn on a relative basis only. Numerical differences between response values can not be quantified because each respondent's assessment and understanding of the intervals between the response categories will vary. In general, results from specific questions on this survey are qualitative and are intended to measure the performance of the AWWS or make general improvements and modifications to the wind warning systems in the COATS region.

5.2. Survey Methodology

A questionnaire format was developed based on the set of information that the research team desired to collect from survey respondents. The same questions were used for respondents at each location, with slight modifications to include details on the corresponding location. These survey questionnaires are shown in Appendix C. This survey was targeted to travelers who are likely to travel through either of the two wind warning system locations in Oregon. Based on input from ODOT personnel, it was assumed that motorists who drive on Yaquina Bay Bridge are likely to be the residents of Newport and other communities in Lincoln County. The AWWS between Port Orford and Gold Beach (Wedderburn) covers a stretch of 27 miles of US Route 101. The travel pattern on this corridor suggests that most of the travel on this corridor is by residents of Coos and Curry Counties in Oregon.

The research team determined that the best method of survey distribution for evaluating the systems in Oregon was to send survey questionnaires by mail and receive the responses through a postage paid envelope provided along with the survey questionnaire. More details on the reasons for choosing this method of distribution can be found in the survey plan document in Appendix A.

The survey questionnaires were mailed out in May 2004, because the wind events are most frequent in November to March season and the research team wanted the respondents to be able to recollect high wind experience to answer the relevant questions. To improve the rate of response, survey respondents were given an opportunity to request a copy of the results and a chance to enter a $100 drawing. Two winners were selected from respondents to questionnaires for each system.

Drivers of commercial or high-profile vehicles would likely be more concerned about high wind conditions; therefore, these respondents were targeted separately through a list of trucking companies with the help of ODOT’s Motor Carrier Transportation Division. Identical survey instruments were used for trucking companies and the general public; consequently, their responses were combined in the analysis.

Response rates are shown for each survey in Table 5-1. The desired number of responses shown in Table 5-1 was calculated based on the assumption that the expected response proportion of “yes” and “no” for a question with two answer options would be 50 percent. The desired number of responses was also for a confidence level of 95 percent and a confidence interval of 5 percent (i.e. the results of the survey have an accuracy of ± 5 percent). These assumptions resulted in a more conservative estimate of the desired number of responses. Though it can be seen that the number of responses was only 343 for the South Coast survey, which was less than the desired number, the analysis results presented below are all statistically valid because most questions have more than two answer options, and because actual responses on questions with two answer options were not equally balanced between responses.

Table 5-1: Survey Distribution Locations and Response Percentages

System Location	Counties	Surveys Distributed			Survey Responses	Responses Desired	Pct.
		Motorists	Truckers	Total			
Yaquina Bay	Lincoln	2,200	200	2,400	407	384	17
South Coast	Coos Bay, Curry	2,200	200	2,400	343	384	14.3

5.3. Analysis Methodology

Respondents had the option of responding to the survey by answering only a partial set of questions from the questionnaire. Percentages are based on the total number of survey respondents, so there was a need for an “unknown” or “no response” category for each question. In addition, if more than one option was selected for questions requiring only a single response; all responses from that individual to that particular question were omitted from the statistical analysis. This was done to avoid biasing the results by arbitrarily choosing which option among several selected by the respondent was to be included. Failure to comply with written instructions on the survey form also resulted in omission of that respondent's particular response from the data analysis (e.g. adding a response option of their own).

The responses were analyzed using various summary statistics, including percentages, frequencies, and means. To provide insight into differences between survey responses, t-statistic and chi-square analyses were used. Typically, the hypothesis tested with chi-square analysis is whether or not two different samples are different enough in some characteristic or aspect of their behavior that we can generalize from our samples that the populations from which our samples are drawn are also different in the behavior or characteristic. The results of chi-square analyses are summarized in Appendix D. It should be noted that an "association" observed as the result of a chi-square test does not equal "causation"; an observed relationship between two variables is not necessarily causal. The results of cross-tabulations comparing responses on various questions are detailed in Technical Memorandum 1 (16).

5.4. Demographic Characteristics

Demographic questions were asked to investigate whether there were any significant differences in the responses for different demographic groups.

Respondents were asked for the zip code of their primary residence. Figure 5-1 and Figure 5-2 show the distribution of the respondents among different zip codes in the region for South Coast System and Yaquina Bay System, respectively. The "Others" category for the zip codes includes all the zip codes which had eight or fewer respondents.

Figure 5-1: Geographic Distribution of South Coast System Respondents

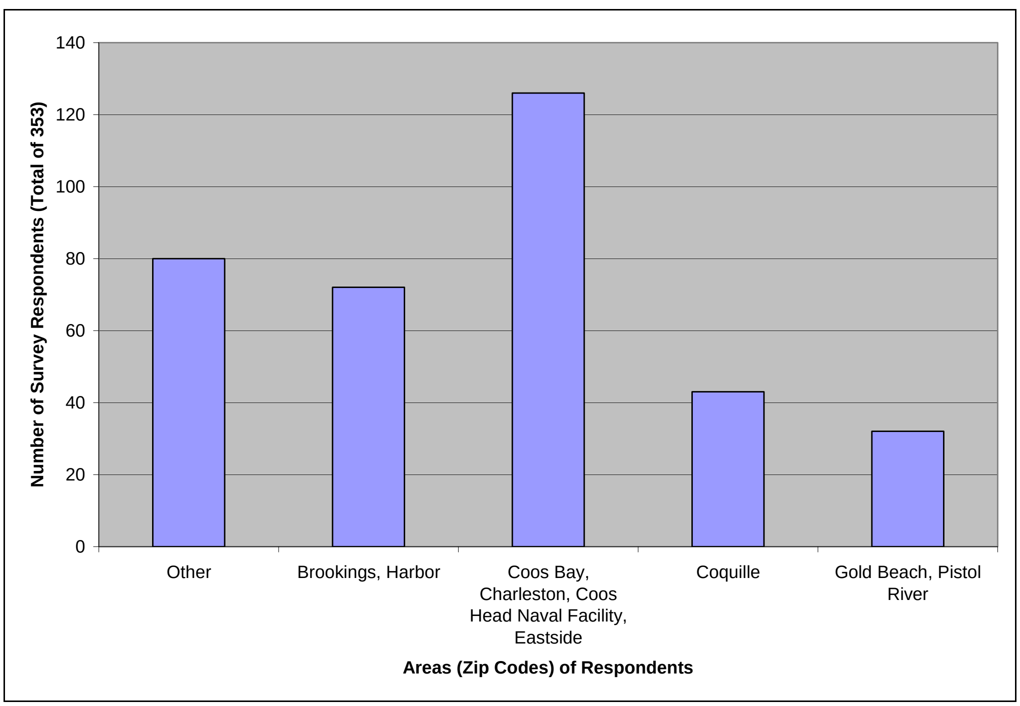
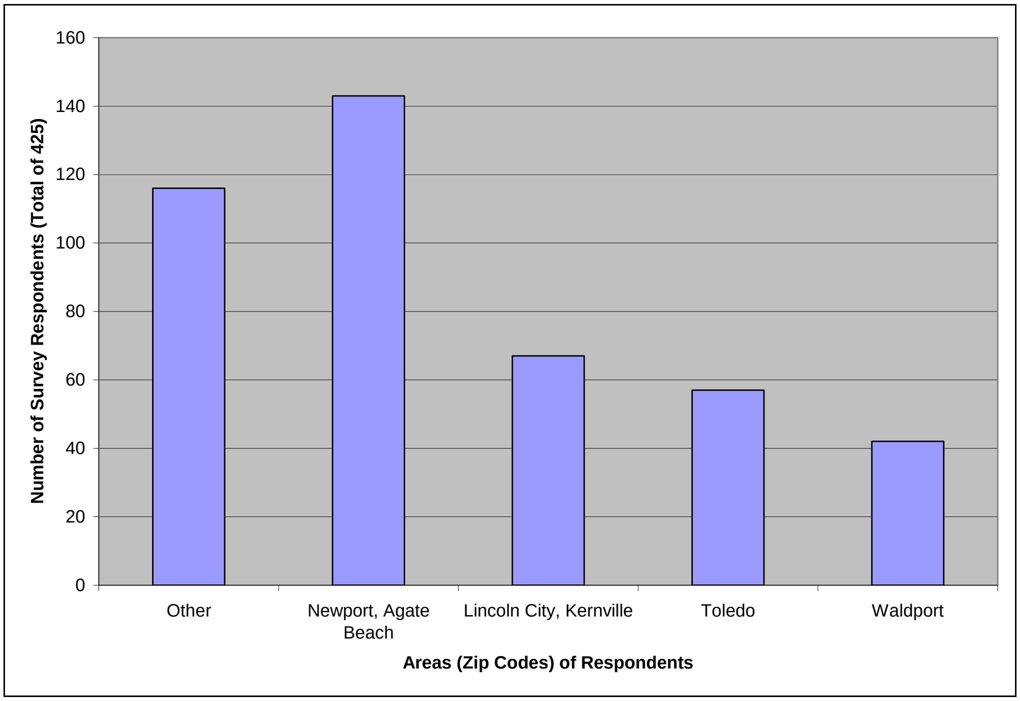


Figure 5-2: Geographic Distribution of Yaquina Bay Bridge System Respondents



The majority of respondents to both surveys were males – 67.4 percent of respondents to the South Coast system and 62.7 percent of respondents for the Yaquina Bay system. Figure 5-3 shows the distribution of gender among survey participants.

Figure 5-3: Gender of Survey Respondents

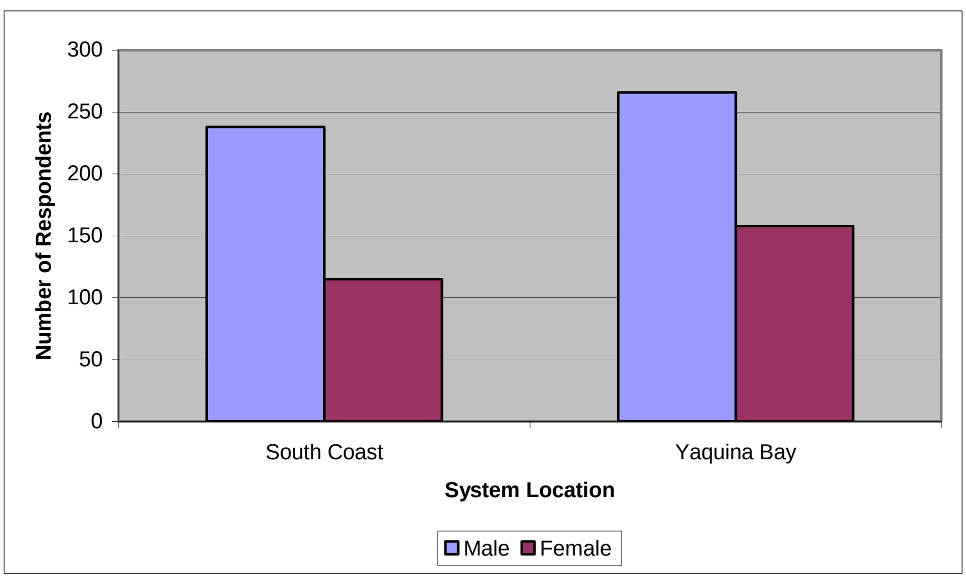
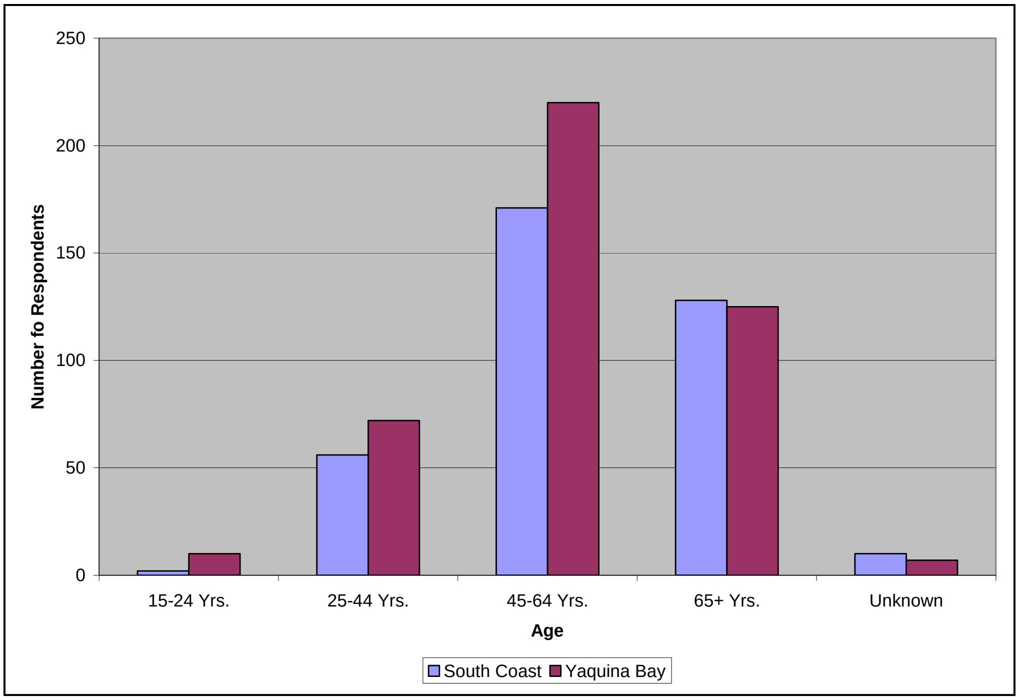


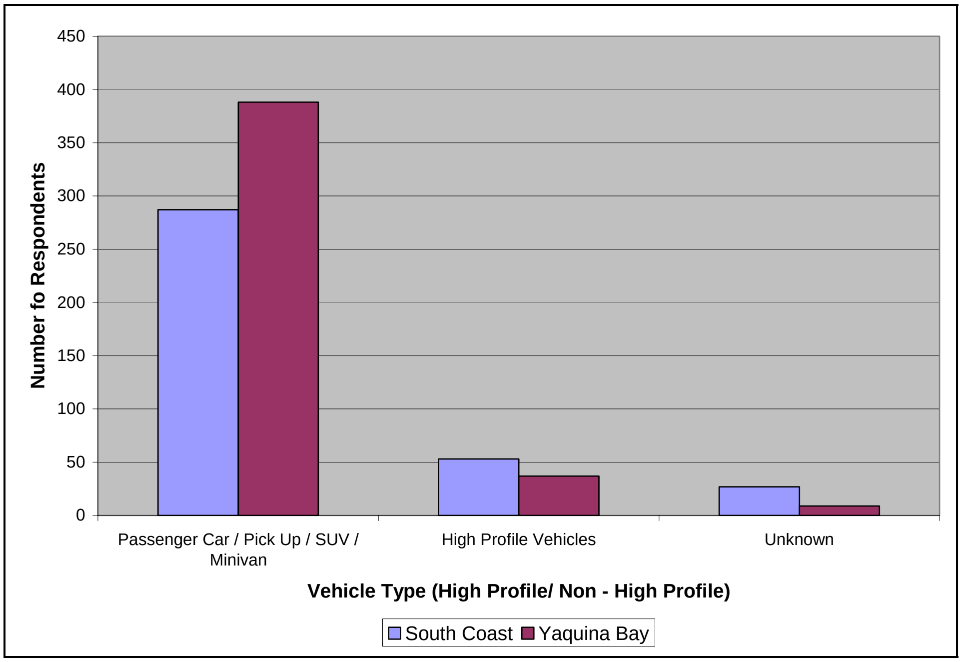
Figure 5-4 displays the age distribution of survey respondents. Participants could choose from four age categories. People in the 45-64 year old category responded the most, comprising approximately half of the respondents in each survey. The average age for respondents to the South Coast system survey was 55.3 years, while the average age for Yaquina Bay system respondents was 53.7 years. The average age was calculated using the middle point of the age ranges in the questionnaire (e.g. 19.5 was used for the 15-24 yrs. range).

Figure 5-4: Age of Survey Respondents



"Passenger car / pick up / sport utility vehicle / minivan" was the category of vehicles most often used by respondents for both systems. The vehicle categories listed on the survey were re-grouped into high-profile vehicles and non-high profile vehicles; the distribution of responses regarding these vehicle types is shown in Figure 5-5.

Figure 5-5: Vehicle Type Normally Driven by Survey Respondents



Because of the over-sampling of commercial vehicles, the vehicle mix at these locations is expected to have a higher percentage of high-profile vehicles than the percentage of respondents who normally drive high-profile vehicles.

Of respondents who indicated their primary vehicle type, 14.4 percent of South Coast system respondents and 8.5 percent of Yaquina Bay Bridge respondents indicated a high-profile vehicle. Excluding those who did not indicate their primary vehicle type, these values were 13 and 6.4 percent of respondents for the South Coast system and Yaquina Bay system, respectively. From the traffic counts at nearby automatic traffic recorder (ATR) stations, the percentages of heavy vehicles are estimated to be 8.7 percent for South Coast system and 5.1 percent for Yaquina Bay system[2].

5.5. Travel Characteristics

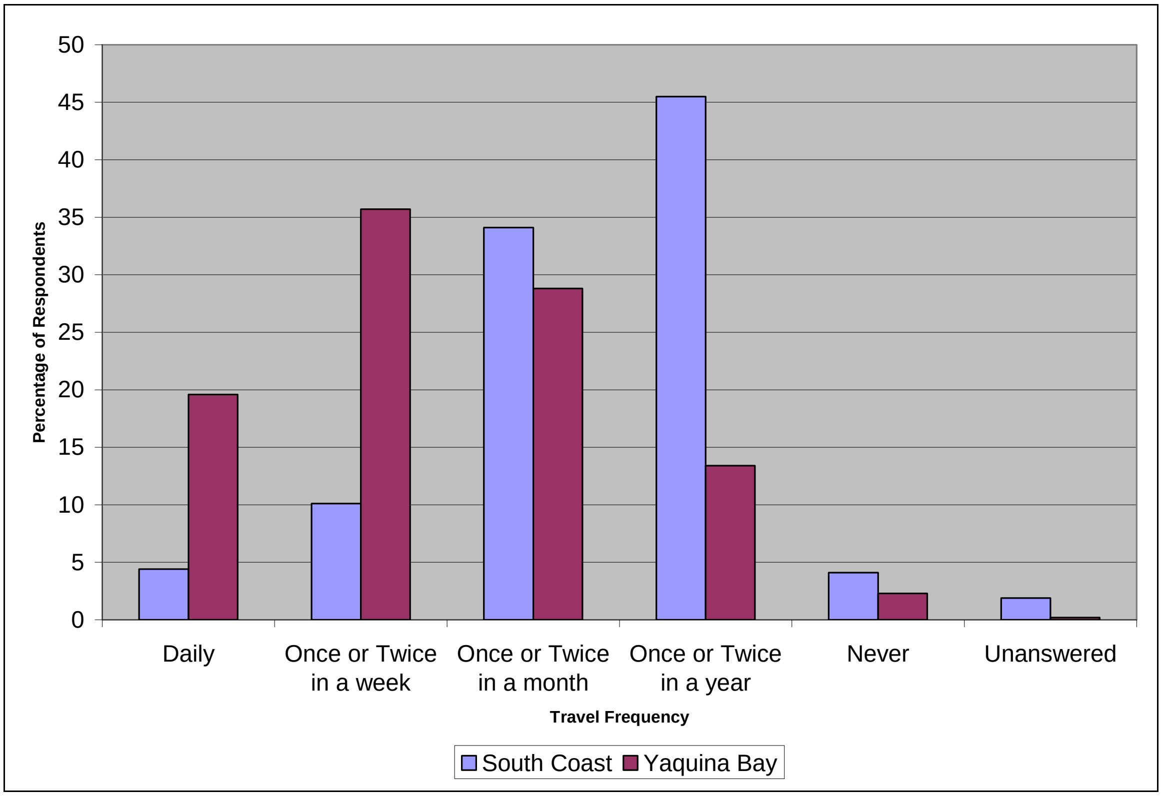
Travelers were asked the questions in this section of the survey to indicate travel frequency through the system locations, what seasons they travel through these locations, and what resources they use to obtain travel information.

The first question on each survey asked respondents to estimate how often they travel through the AWWS locations, selecting among a list of categories. Survey responses are shown in Figure 5-6. The most common travel frequency category for respondents to the Yaquina Bay survey was

[2] The ATR stations do not classify the recreational vehicles / campers as heavy vehicles and the high profile vehicle percentages include recreational vehicles / campers.

"once or twice in a week," while the most frequent choice for the South Coast system was "once or twice in a year".

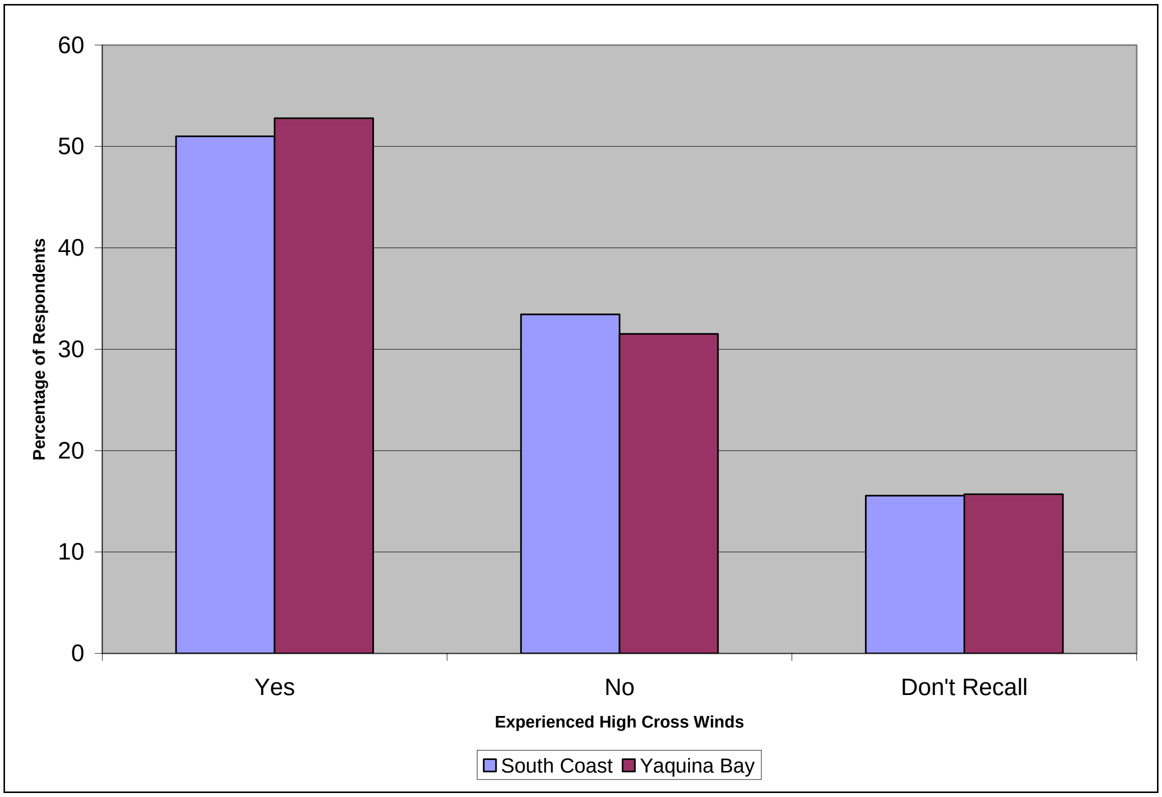
Figure 5-6: Travel Frequency of Respondents



Accordingly, the average number of trips per year for the respondents of the South Coast System survey was estimated to be 52 trips per year and the average number of trips for respondents of the Yaquina Bay System survey was estimated to be 203 trips per year. This confirms the assumption in the survey design that Yaquina Bay Bridge traffic is more commute-oriented while traffic through the South Coast system is mostly long-distance.

The second question in the survey asked the respondents whether they have encountered high winds while driving through the system locations since November 2003. The surveys were distributed in May 2004. Figure 5-7 shows that a little more than half of the respondents for each survey reported experiencing high winds at these locations, while about 15 percent of respondents could not recall. It should be noted that the question specifically asked whether the respondents experienced high cross winds after November 2003. The time gap between survey response and respondents' experience driving through the corridor may explain a reasonable number of respondents not being able to recall.

Figure 5-7: High Wind Experience of Respondents

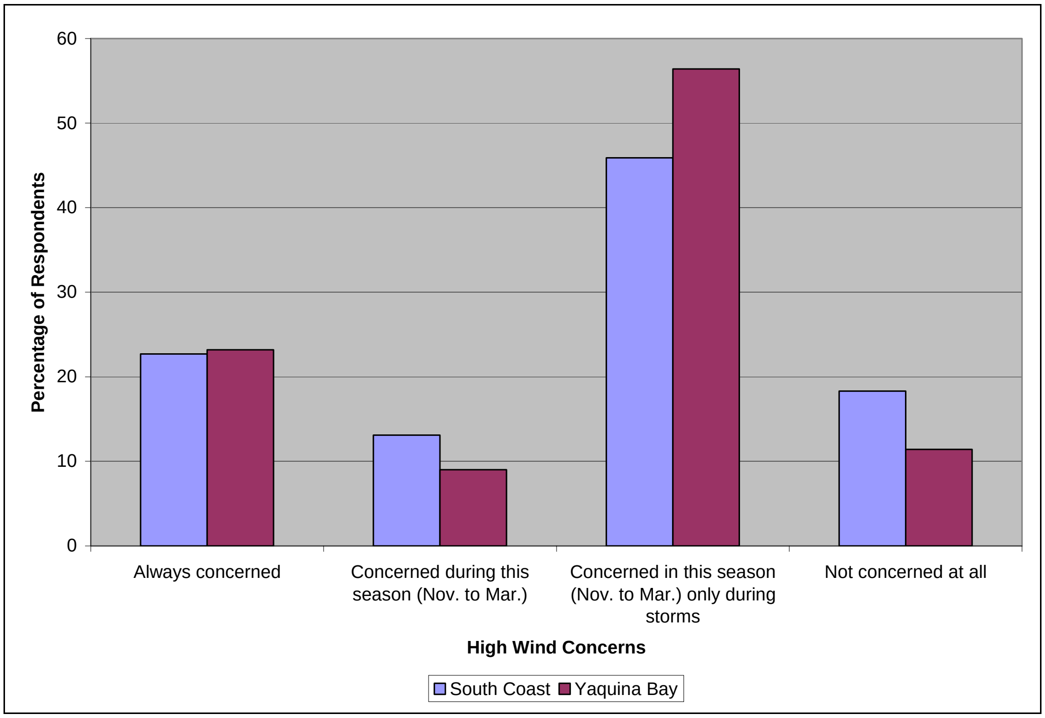


5.6. Traveler Perception of High Winds

One of the objectives of the evaluation was to determine the level of concern among respondents about high cross winds and to identify their specific issues of concern.

The respondents were asked how concerned they were about driving in high cross winds. Most of the respondents said that they were concerned about high cross winds only during storms in the season (November to March) for both system locations, as shown in Figure 5-8.

Figure 5-8: High Wind Concerns of Respondents

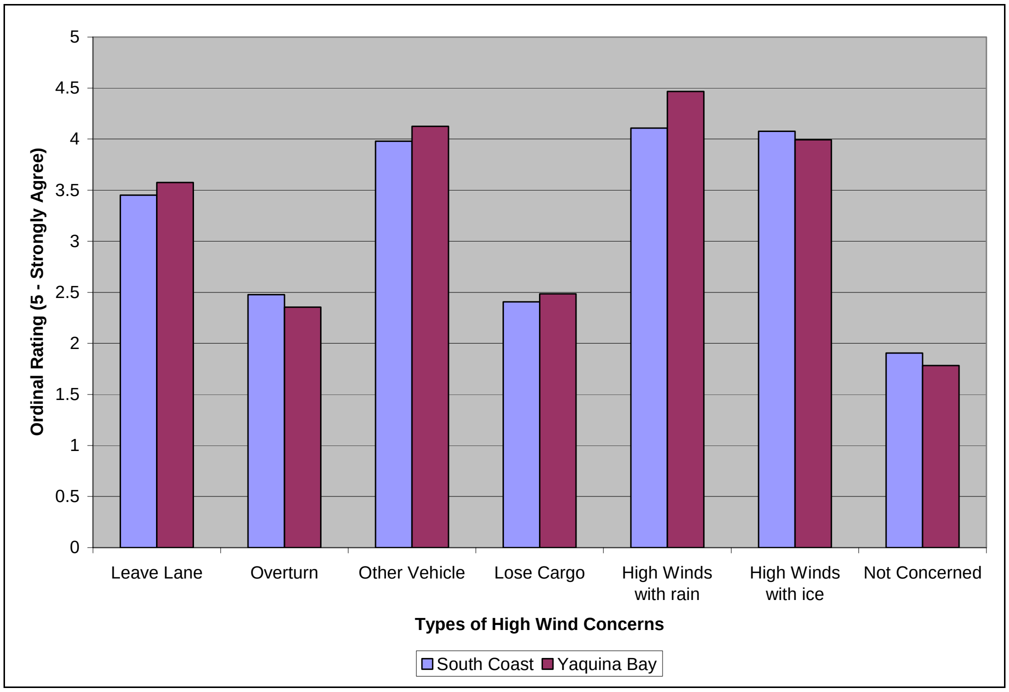


The respondents were asked what their concerns were while driving in windy conditions. A set of statements were given, and the respondents were asked to rate how much they agreed with each of those statements on a 1-to-5 Likert scale. This was an ordinal rating question with five levels of rating (5 – Strongly Agree, 4 – Somewhat Agree, 3 – Neutral, 2 – Somewhat Disagree, 1 – Strongly Disagree). The statements that respondents were asked to rate in this question are as follows.

- My vehicle may leave its lane
- My vehicle may overturn
- Other vehicles may overturn or leave their lane
- I may lose part of my cargo
- I'm more concerned about high winds with rain
- I am more concerned about high winds when it is icy
- I am not at all concerned

Figure 5-9 shows the mean values of the ratings for these questions. As a majority of the respondents were of passenger car / pickup / sport utility vehicle / minivan type, it is not unexpected to see that "my vehicle may overturn" and "I may lose part of my cargo" had a mean rating less than 2.5 (i.e. respondents generally disagree with these statements). It should be noted that "I'm not at all concerned" category received an ordinal rating less than 2. This may mean that most travelers at these two system locations have some level of concern about high cross winds.

Figure 5-9: Types of High Wind Concerns for Respondents



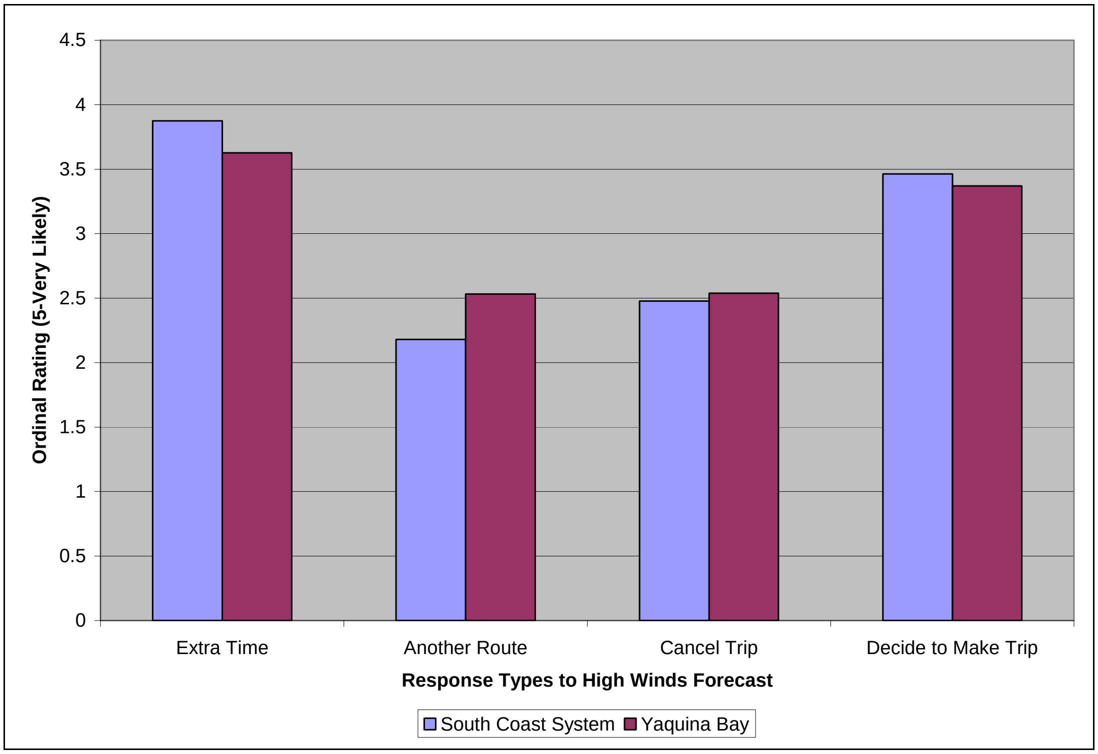
5.7. Traveler Perception of High Wind Forecast

The present perception of high wind forecasts will influence how well the travelers receive a high wind warning message. The respondents were asked how likely they were to perform any of the following actions.

1. Allow extra time for the trip
2. Take another route if applicable
3. Cancel the trip
4. Decide to make the trip

Each question was scored with an ordinal rating question on a 1-to-5 scale, with 5 meaning “very likely” and 1 meaning “very unlikely”. The mean values of the ordinal rating for each of these actions are shown in Figure 5-10. The mean response for the “take another route” statement was calculated based on the subset of respondents who stated that there was an alternate route. The responses between “decide to make the trip” and “allow extra time for the trip” seemed to be somewhat redundant, based on the consistency in their answers to these questions.

Figure 5-10: Respondents' Stated Responses to High Wind Forecast



5.8. Traveler Awareness of AWWS

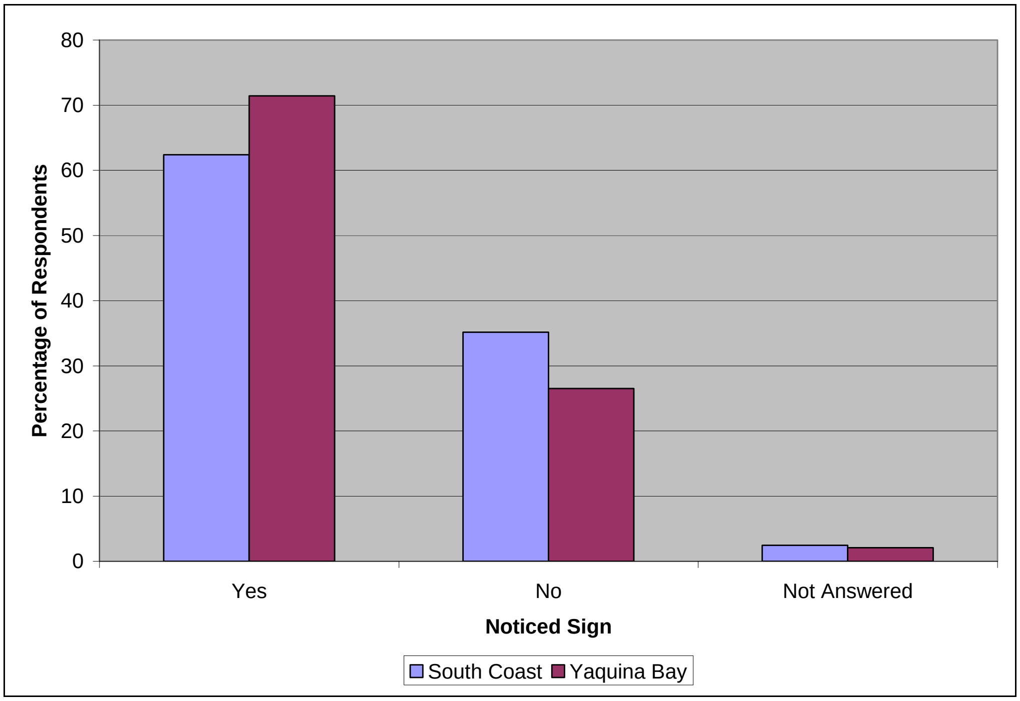
Another aspect of the motorist survey was to determine how aware motorists are of the presence, purpose and functions of these wind warning systems. The respondents were asked the following questions to determine their level of awareness of the system:

1. Have you seen this sign?
2. Have you seen the lights on top of the sign flashing?
3. Were there high winds present when the sign was on?
4. Would you find it helpful if wind speeds were posted on the sign?

These were multiple-choice questions. The first question needed to be answered by all the respondents, and the next three questions did not need to be answered by all depending on their response to the first question.

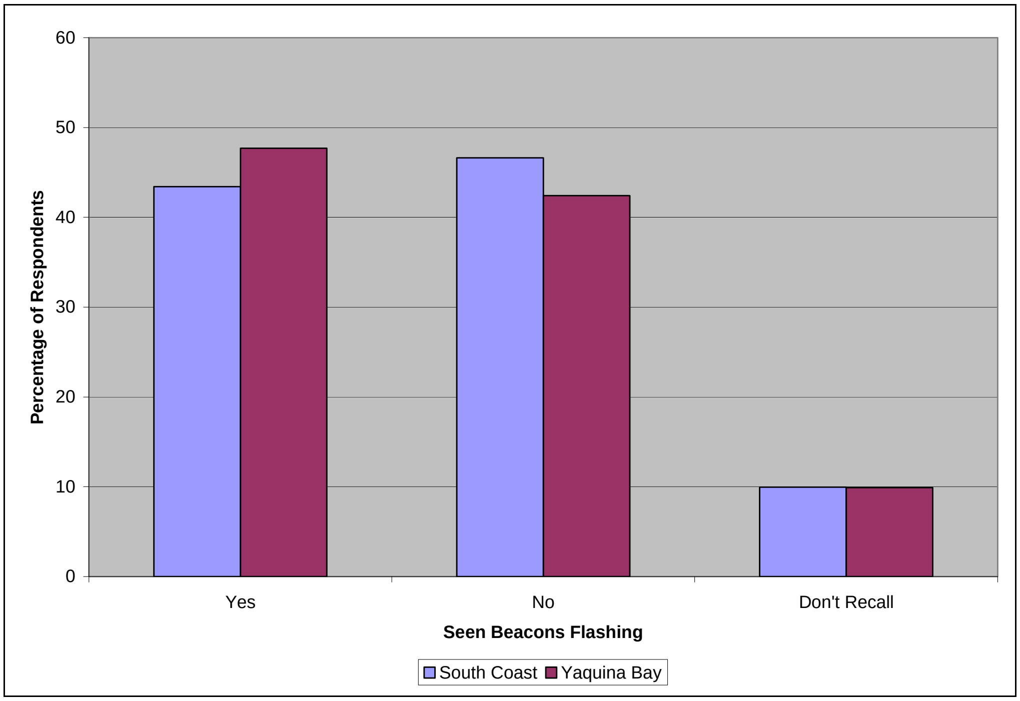
Figure 5-11 shows the spread of the responses to the question about sign awareness. It should be noted that more than 75 percent of the respondents for the Yaquina Bay Bridge system have noticed the sign and more than 60 percent of the respondents have noticed the sign for the South Coast system. The highway has five lanes at Port Orford and four lanes at Wedderburn (i.e. the two ends of the system location), while the highway is just one lane each way on Yaquina Bay Bridge. This may partly explain the fact that a higher percentage of respondents noticed the Yaquina Bay Bridge signs than the South Coast signs. Another reason for the higher awareness of the Yaquina Bay system may be that there are more commuters traveling daily over the Yaquina Bay Bridge than through the South Coast system.

Figure 5-11: Respondents' Awareness of Warning Sign



Only respondents who stated that they have noticed the high wind warning signs were asked to answer the second question (7b): Have you seen the lights on top of the sign flashing? Figure 5-12 shows the percentage of respondents that have seen the beacons flashing and the percentage of respondents that have not seen the beacons flashing. The percentage of respondents that said "No" to this question includes respondents who have not traveled through this system location when high winds were not present.

Figure 5-12: Respondents Who Noticed Sign and Have Seen Beacons Flashing*

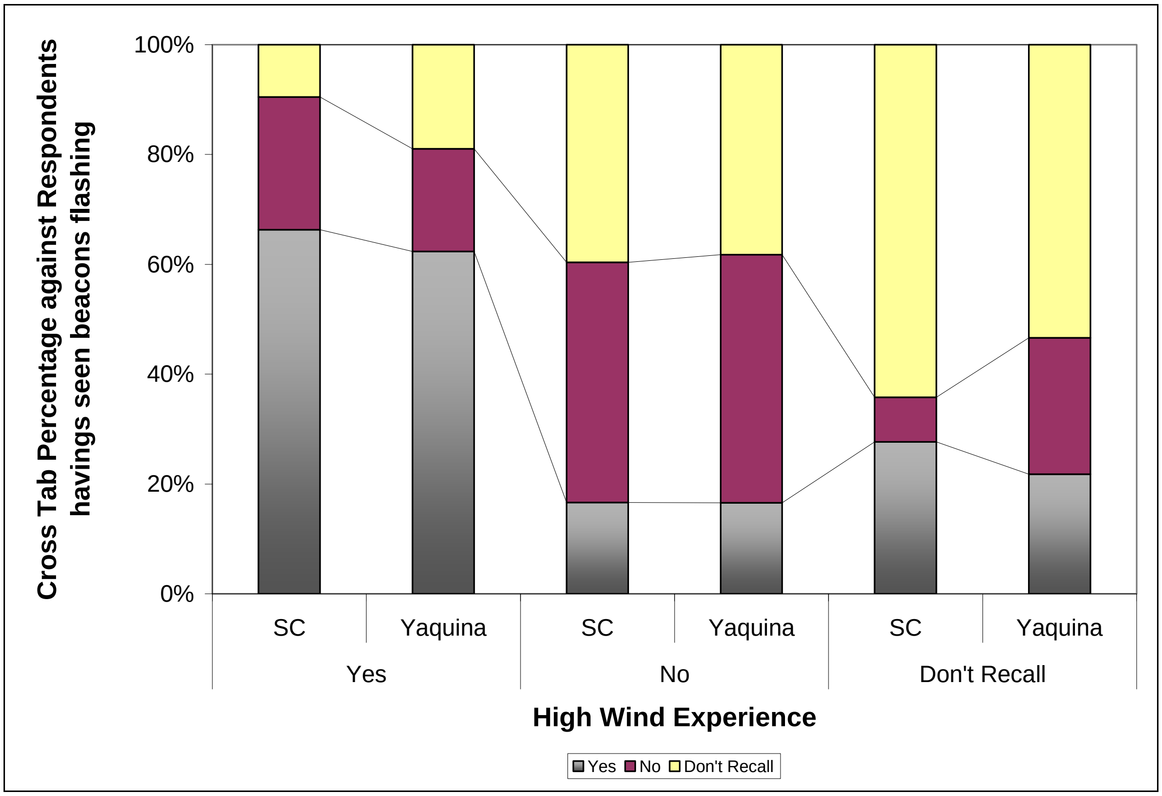


* "No" most likely represents drivers that have driven through the locations only during non wind conditions

About half of the respondents for both systems who have seen the static warning signs stated that they have not seen the beacons flashing. This could be for several reasons. First, they may have driven through the system locations when high winds were not present; only about half of the respondents said that they experienced high winds when they traveled through these system locations. Second, they may have driven through when high winds were present, but did not notice the beacons were flashing. Third, high winds may have been present, but the flashing beacons did not activate. Respondents who said they have not seen the beacons flashing are most likely the respondents who drove through the system locations only during normal (i.e. no high cross winds) conditions between November 2003 and June 2004.

Figure 5-13 shows that more than 70 percent of the respondents either said they saw the beacons flashing or that they could not recall whether they saw the beacons flashing for both the systems. Conversely, only 20 to 25 percent of respondents indicated having experience with high winds in these areas but not seeing the flashing beacon.

Figure 5-13: High Wind Experience vs. Seen Beacons Flashing



5.9. System Functionality

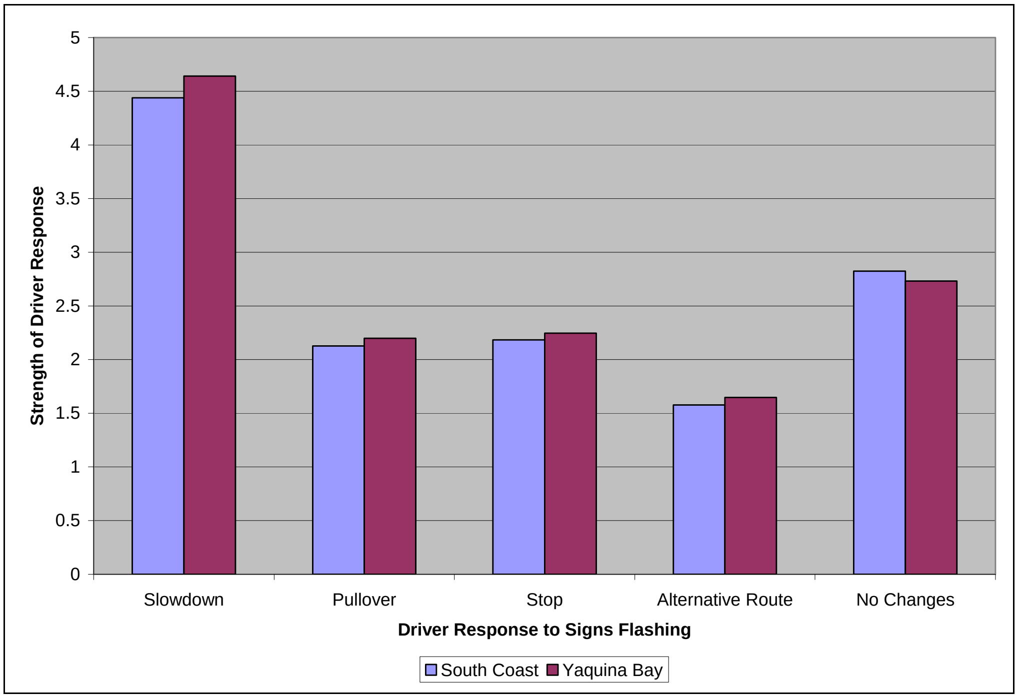
A significant purpose of this survey was to evaluate how drivers would react to a high wind warning message by AWWS. Drivers' reaction will depend on their perception of the reliability of the system. The respondents were asked two sets of questions to determine their perception of AWWS.

The first set of questions asked the respondents to express how likely they were to do a given set of actions in response to a warning message from AWWS. The set of reactions included the following:

1. Drive more slowly
2. Pull over to the shoulder and wait
3. Stop at a nearby area and wait
4. Take an alternate route, if available
5. Make no changes

This was an ordinal rating question with five levels of rating, similar to question 6. The mean rating of the respondents on how likely they were to take these actions is shown in descending order in Figure 5-14. Most of the respondents agreed with "drive more slowly" option with a mean response rating of about 4.5. All respondents were asked to rate their likelihood of taking an alternate route, and the mean rate includes the responses from drivers who do not have an alternate route. This may explain the low rating of this option, as about half of respondents reported not having a viable alternative route.

Figure 5-14: Stated Response to AWWS Warnings by Respondents

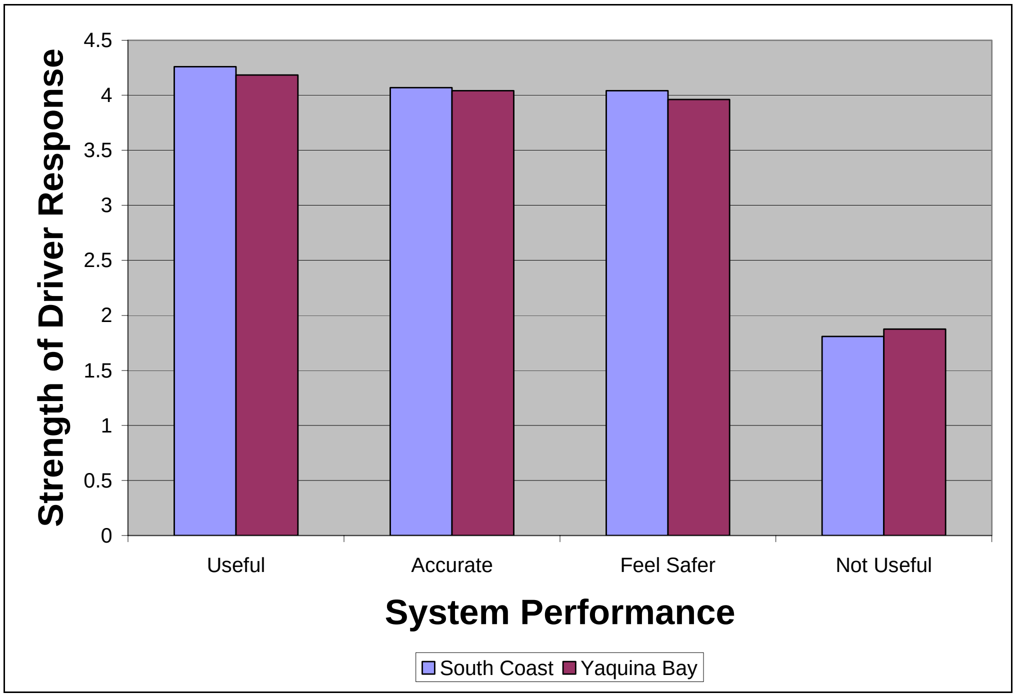


The second set of questions related to respondents' assessment of system performance. Respondents were asked to rate their agreement with the following set of statements.

1. This system would provide me with useful information
2. The system would accurately indicate when high winds are present
3. I would feel safer driving this road knowing the system is in place
4. This system does not sound useful

This question was also scored on a 1-to-5 ordinal rating scale, with 1 representing strongly disagree, and 5 representing strongly agree. The mean rating of respondents for these statements are shown in Figure 5-15. The response to the statement, "This system would provide me with useful information" received the highest average rating (4.26 and 4.18 for South Coast and Yaquina Bay Bridge systems, respectively) on the ordinal scale explained above. The respondents also agreed with the statements regarding system accuracy and improved safety with an average score of about 4 for both the systems. Survey respondents disagreed with the statement "This system does not sound very useful" on an average scale of about 1.75 for both the systems.

Figure 5-15: Perception of AWWS Performance



5.10. Summary of Motorist Survey Analysis

Table 5-2 shows that most of the survey respondents thought the sign would provide them useful and accurate information and a significant percentage of the respondents have seen the sign.

Table 5-2: Summary of Measures of Effectiveness (MOE) Results from Motorist Survey

MOE	Measures	
	South Coast	Yaquina Bay
System Awareness	**84** percent of the respondents who have driven through the location during high cross winds have seen the beacons flashing.	**86** percent of the respondents who have driven through the location during high cross winds have seen the beacons flashing.
System Usage	**90** percent of the survey respondents are “very likely” or “likely” to slow down when high wind warning is on.	**92** percent of the survey respondents are “very likely” or “likely” to slow down when high wind warning is on.
Sign Clarity	More than **60** percent have seen the sign	More than **75** percent have seen the sign
Message Credibility and Reliability	**84** percent of the survey respondents either “strongly agree” or “agree” that the system will provide them accurate information	**80** percent of the survey respondents either “strongly agree” or “agree” that the system will provide them accurate information

6. TECHNOLOGY ASSESSMENT

Another aspect of evaluating the AWWS is to look at the AWWS technology itself. This seeks to answer whether the AWWS have functioned as designed. This is especially important in this evaluation since both Oregon AWWS were developed as custom applications in-house, including conceptual design, integration of system components, and development of automation algorithms, logic programming, and system installation and testing.

This chapter evaluates the AWWS technologies. First, Theory of Operations (TOO) diagrams were developed to understand the physical architecture and the communication between system components. The reliability of the system was assessed by comparing the wind speeds measured at a nearby location to the system and the activation records of the system. This involved contact with responsible maintenance people and a review of all available records that document maintenance history at each site. System reliability – the extent to which the system operates continuously with a minimum of maintenance, either scheduled or unscheduled – was established through reviews of activation records, and telephone interviews with the responsible maintenance staff.

6.1. Theory of Operations

The National ITS Architecture is a framework spanning all of ITS, in order to show how systems exchange information to provide certain transportation system functions, called market packages. A Theory of Operations (TOO) is what explains how the architecture provides a transportation service. Theory of Operations is a depiction of how the architecture of a system works (i.e. how requirements are satisfied by sub systems/institutions working together). TOO also lays out the interoperability roles, responsibilities and procedures. TOO is aimed at answering the following questions:

1. Who sends what to whom and when?
2. Who starts/contributes/ends the transactions?

The following physical entities of AWWS are used in the TOO diagrams shown in this section.

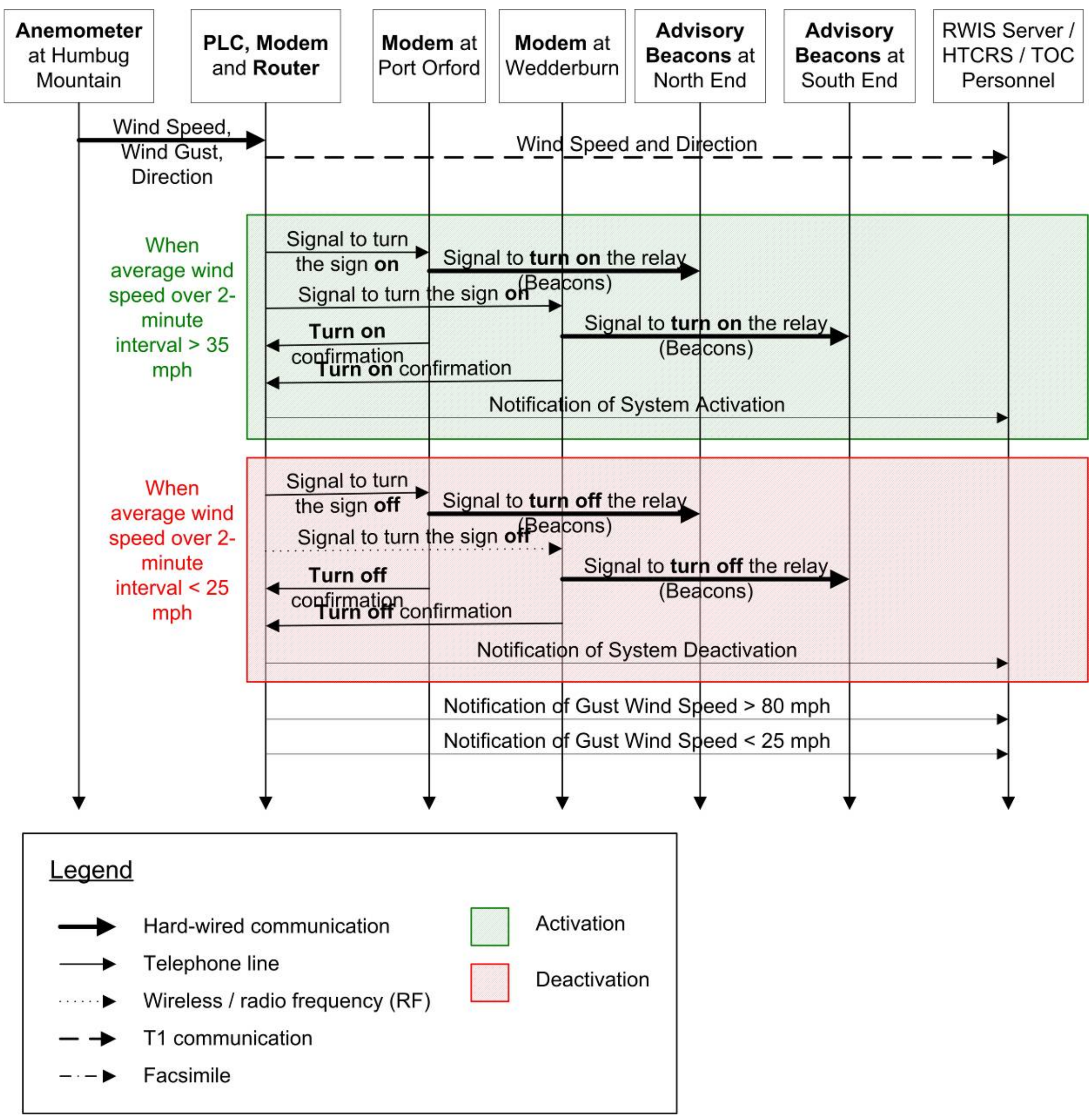
- Anemometer / RWIS: Measures average wind speed, wind direction, gust speed and gust direction.
- Field Controller: Controls the activation and deactivation of certain devices based on programmed logic.
- Server at TOC: A computer that received data from a field device and controls activation and deactivation of certain devices.
- Static Signs with Flashing Beacons: Normal traffic signs with warning messages and beacons installed on top of the signs.
- Changeable Message Signs (CMS): Electronic signs that can display any message activated by controllers
- Maintenance Crew: Two or more maintenance staff equipped with vehicles and appropriate devices

- TMC/TOC Personnel: Personnel at Traffic Management Centers (TMC) in California or Traffic Operations Centers (TOC) who monitor the traffic and other data from field devices
- CHP/OSP (Highway Patrol): California Highway Patrol / Oregon State Police
- Media/Consituents: This includes DOT maintenance personnel, highway patrol and other constituents shown in Appendix H

6.1.1. South Coast System

The South Coast system includes an anemometer and a programmable logic controller (PLC) with built-in auto-dialer and modem at Humbug Mountain, where the wind speeds are typically

Figure 6-1: Theory of Operations Diagram (South Coast)

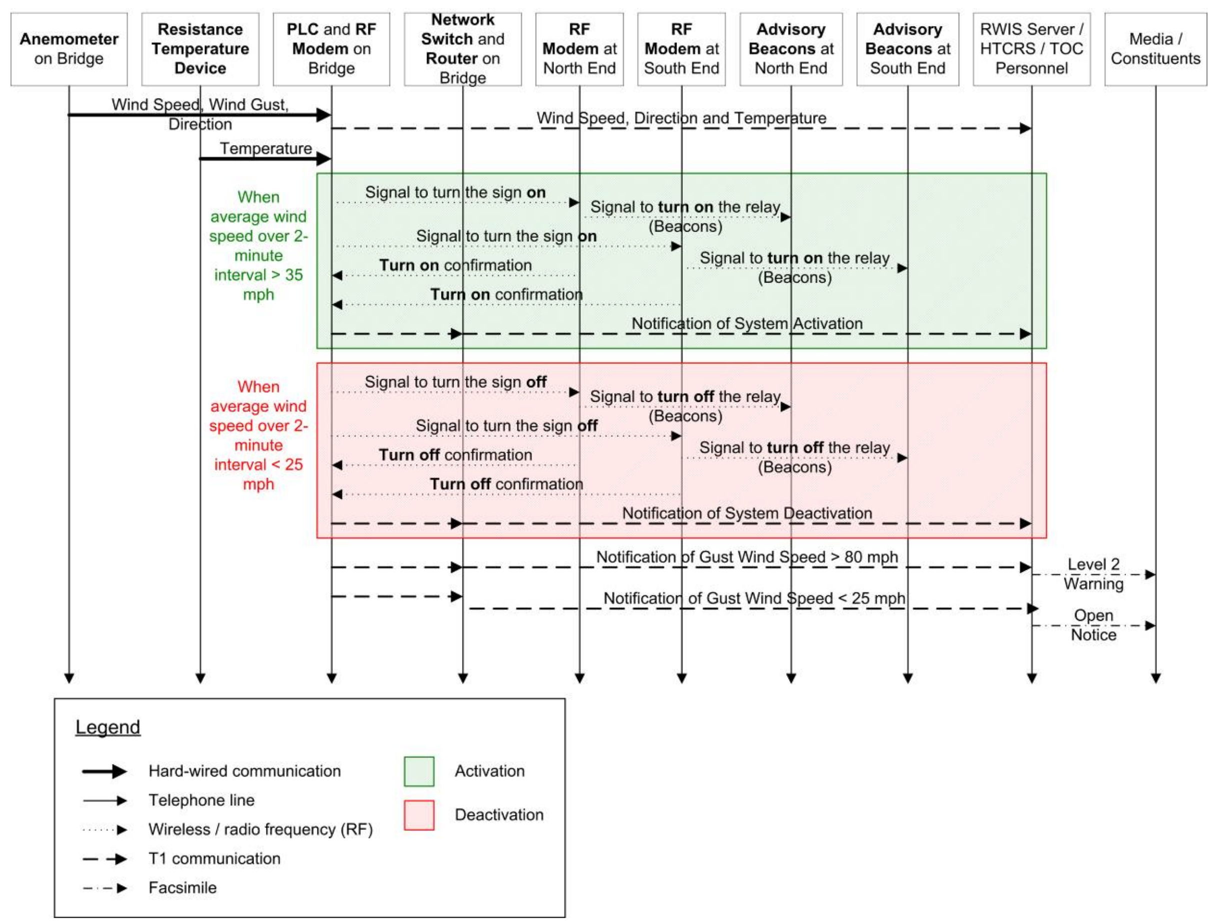


the highest in the corridor. At Port Orford and Wedderburn, where the signs are located, the system includes the advisory signs with flasher relays and beacons (one per location), along with one PLC (with built-in auto-dialer and modem) at each location. The TOO diagram for the South Coast System is presented in Figure 6-1.

6.1.2. Yaquina Bay System

The Yaquina Bay Bridge system includes an anemometer, resistance temperature device (RTD), PLC, network switch and router, and radio frequency (RF) modem on the bridge itself. For each sign, the system includes one advisory sign with beacons, RF modem and flasher relay at each end. The system also involves direct communication with ODOT maintenance personnel, the Oregon State Police (OSP) and the media, as shown in Figure 6-2.

Figure 6-2: Theory of Operations Diagram (Yaquina Bay Bridge)

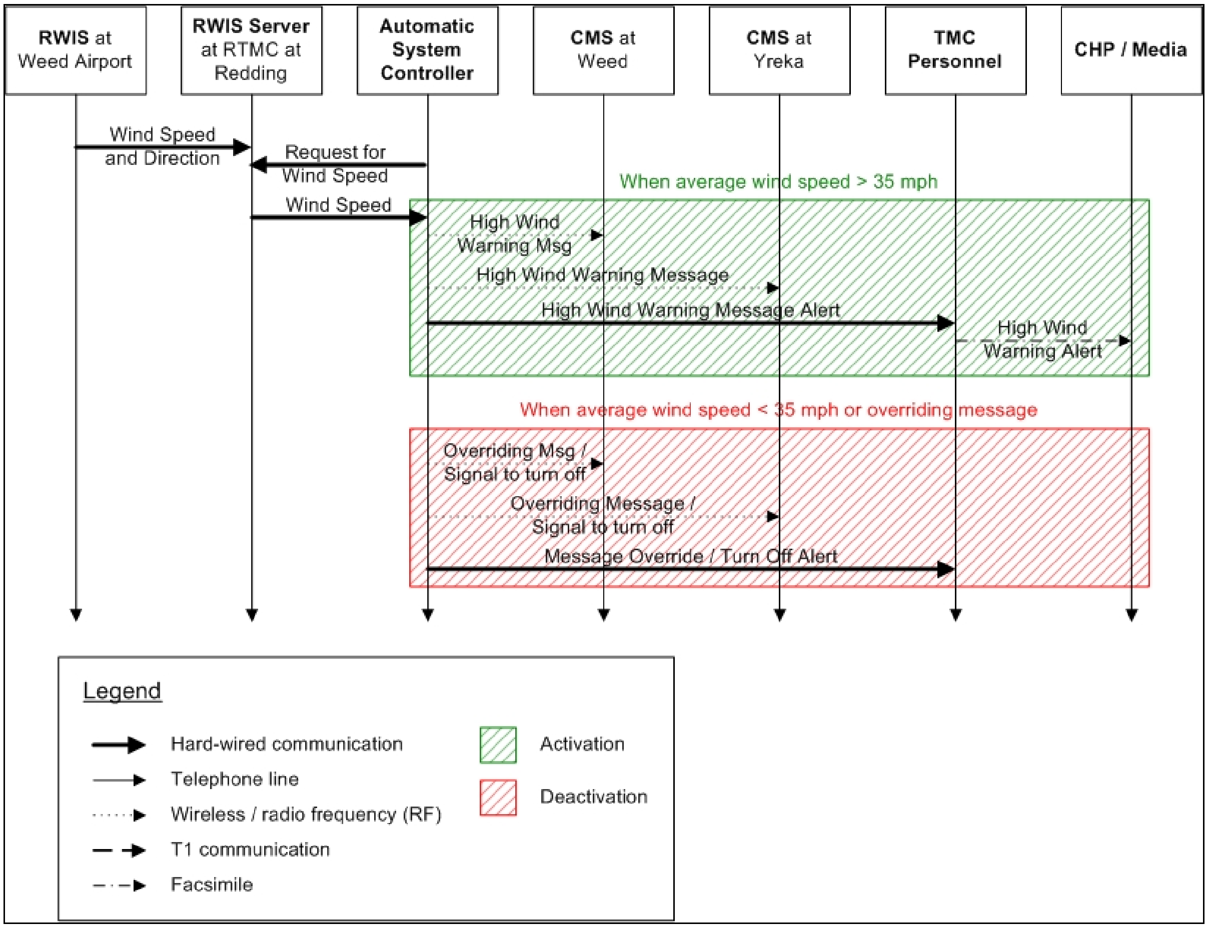


6.1.3. Interstate 5 System

As was mentioned earlier, the Interstate 5 system is not currently fully automated. The TOO diagram portrays how the system has been designed by District 2. When the system is complete, it will include the existing RWIS station at the Weed Safety Roadside Rest Area, existing changeable message signs located at Yreka and Weed, and the RWIS server in the District 2

Transportation Management Center (TMC). The system will also involve TMC personnel, the California Highway Patrol (CHP) and the media, as shown in Figure 6-3.

Figure 6-3: Theory of Operations Diagram (Interstate 5)



6.2. System Accuracy

As indicated earlier, it was important to make sure that the system functioned accurately because a negative perception on the system accuracy by motorists would make the system less effective. System accuracy would best be measured by having an independent anemometer of known accuracy sited at locations with identical wind exposure as the anemometers used in the system. The wind readings could be compared, and records of system activation could be compared with the wind data to see whether the system was activated and deactivated at appropriate thresholds. However, there were no wind observation locations for which identical wind conditions could be assumed.

Therefore, system accuracy was established through two proxy measures. First, maintenance personnel who are familiar with the system locations and use these systems were interviewed regarding their assessments of system accuracy. Second, weather stations near each system were identified. A simple cross analysis between system activation records and the weather observations from these stations was performed.

6.2.1. South Coast System

After its initial design, the South Coast system was modified to automatically notify the Traffic Operations Center (TOC) of system activations and deactivations. Activation and deactivation records for this system are available only from mid-April 2005.

The closest weather station to the South Coast system is the RWIS station at Port Orford. The South Coast system uses the wind speed measurements from the anemometer installed near Humbug Mountain between Port Orford and Wedderburn (Gold Beach). The wind speed measurements from the RWIS station at Port Orford were originally planned to be used for automating the South Coast system. It was subsequently determined that the wind speeds measured by the RWIS at Port Orford are lower than wind speeds by Humbug Mountain as the RWIS was shielded by trees and was also located farther from the ocean front than the south bound lanes.

For the purposes of verifying the activation and deactivation records, weather data from the Port Orford RWIS was used. It should be noted that wind speeds measured at the Port Orford RWIS station are typically less than the wind speeds at Humbug Mountain (i.e. the location of the AWWS anemometer) because the RWIS station is shielded from the ocean front by trees. A comparison of the wind speeds measured by the Port Orford RWIS at the time of system activation and deactivation and the wind speeds measured by the AWWS is provided in Table 6-1.

The following logical expressions were used for the verification of the activation and deactivation of the system, where w_p is the wind speed measured at the Port Orford RWIS station.

1. If the sign is activated and $w_p > 30$ mph, then the sign activation is *verified* and the activation is *accurate*. This uses a lower threshold than the AWWS because of the lower wind speeds typically measured at the Port Orford RWIS.

2. If the sign is being deactivated and $w_p < 20$ mph, then the sign deactivation is *verified* and the deactivation is *accurate*.

3. If $w_p < 30$ mph during sign activation or $w_p > 20$ mph during sign deactivation, then the sign activation or deactivation is *not verified*.

About 83 percent of the activation records could be reviewed using the wind speed data from Port Orford RWIS. The remaining activation and most of the deactivation records could not be verified with the wind speed data from Port Orford RWIS. It should be noted that “Not Verifiable” does not mean false activation or deactivation as the wind speeds vary significantly among different locations and the critical wind speeds are expected at Humbug Mountain.

Table 6-1: Verification Results for South Coast System

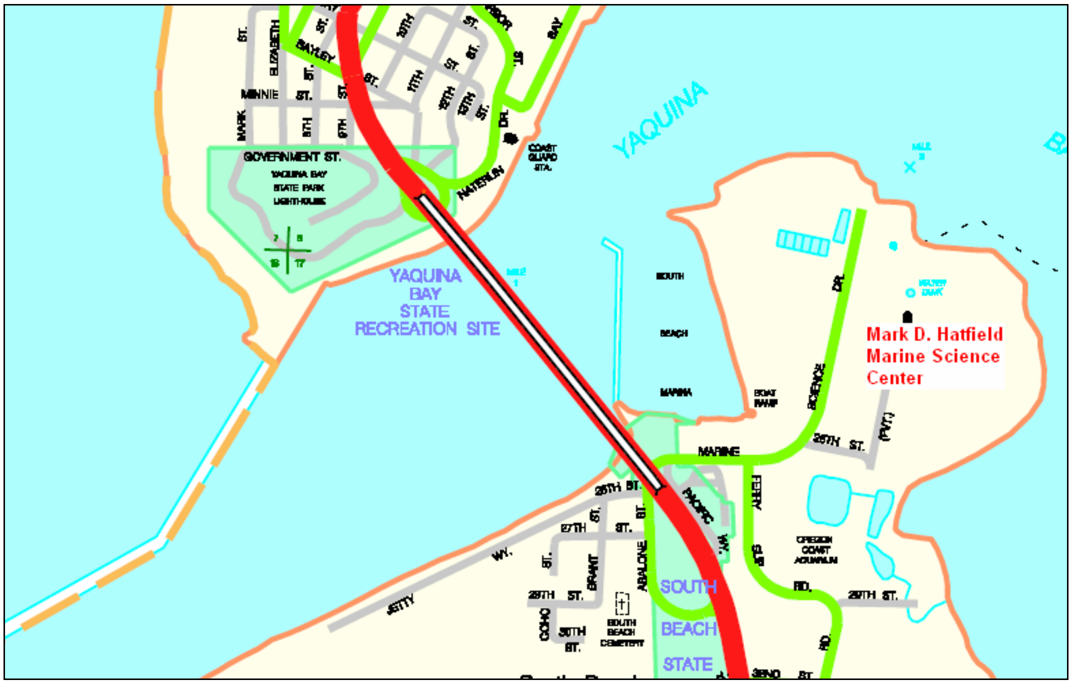
Event	Device Status	Date/Time(PDT)	RWIS Avg. Wind Speed	Device Status	Date/Time(PDT)	RWIS Avg. Wind Speed	Activation Verification	Deactivation Verification
1	On	4/12/2005 3:09 AM	62	Off	4/12/2005 3:39 AM	29	Verified	Not Verifiable
2	On	5/18/2005 1:12 PM	49	Off	5/18/2005 1:32 PM	34	Verified	Not Verifiable
3	On	5/18/2005 1:52 PM	53	Off	5/18/2005 3:32 PM	40	Verified	Not Verifiable
4	On	5/18/2005 5:42 PM	48	Off	5/18/2005 6:32 PM	34	Verified	Not Verifiable
5	On	5/18/2005 6:42 PM	31	Off	5/18/2005 6:52 PM	56	Not Verifiable	Not Verifiable
6	On	5/18/2005 7:02 PM	56	Off	5/18/2005 9:32 PM	44	Verified	Not Verifiable

6.2.2. Yaquina Bay Bridge System

Weather data for the time period between December 2004 and July 2005 was collected from the archives of Hatfield Center at Oregon State University (14).The weather station on top of the Hatfield Marine Science Library is shielded by some extent as it is located inside Yaquina Bay, about 0.5 miles from the bridge. Figure 6-4 shows the location of the Hatfield Center relative to the Yaquina Bay Bridge. While the bridge is at a higher elevation than the weather station, it is also closer to the ocean front. Therefore, the wind speeds on the bridge are expected to be higher than wind speeds measured at the Hatfield Center.

The following logical expressions were used for the verification of the activation and deactivation of the system, where w_h is the wind speed measured at the Hatfield Center.

Figure 6-4: Location of Hatfield Center Relative to Yaquina Bay Bridge*



*Source: ODOT ITS Unit

1. If the sign is activated and $w_h > 30$ mph, then the sign activation is *verified* and the activation is *accurate*. This uses a lower threshold than the AWWS because of the lower wind speeds typically measured at the Hatfield center.

2. If the sign is being deactivated and $w_h < 20$ mph, then the sign deactivation is *verified* and the deactivation is *accurate*.

3. If $w_h < 30$ mph during sign activation or $w_h > 20$ mph during sign deactivation, then the sign activation or deactivation is *not verified*.

The verification results are shown in Table 6-2. About 50 percent of the activation and deactivation records could be reviewed using the wind speed data from Hatfield Center. The remaining activation and deactivation records can not be verified with the wind speed data from Hatfield Center.

Table 6-2: Verification Results for Yaquina Bay Bridge

		Hatfield Center Data			Hatfield Center Data			
Wind Event	Activation Date/Time (PDT)	Time (PDT)	Peak Wind Speed in 15 Min.	Deactivation Date/Time (PDT)	Time (PDT)	Peak Wind Speed in 15 Min.	Activation Verified	Deactivation Verified
1	12/13/04 15:51	16:00	36	12/13/04 17:01	17:15	29	Yes	No
2	12/25/04 7:43	7:45	34	12/25/04 16:23	16:15	24	Yes	Yes
3	2/28/05 11:31	11:30	28	2/28/05 12:41	12:45	22	No	Yes
4	3/16/05 11:13	11:00	31	3/16/05 15:37	15:45	21	Yes	Yes
5	3/19/05 14:15	14:30	36	3/20/05 7:05	7:30	41	Yes	No
6	3/20/05 7:55	8:00	35	3/20/05 8:25	8:30	31	Yes	No
7	3/20/05 17:15	17:15	30	3/20/05 20:05	20:00	21	Yes	Yes
8	3/20/05 20:55	21:00	27	3/20/05 21:05	21:15	15	No	Yes
9	3/26/05 3:46	4:00	34	3/26/05 5:42	5:30	31	Yes	No
10	3/26/05 9:24	9:30	33	3/26/05 9:34			Yes	
11	3/26/05 9:44			3/26/05 10:04				
12	3/26/05 10:34			3/26/05 11:44				
13	3/26/05 11:54			3/26/05 13:19				
14	3/26/05 13:34			3/26/05 19:54	20:00	28		No
10-14								
15	3/26/05 21:55	22:00	33	3/26/05 22:25			Yes	
16	3/26/05 22:35			3/26/05 23:25				
17	3/26/05 23:35			3/26/05 23:55				
18	3/27/05 0:05			3/27/05 3:05	3:00	28		No
15-18								
19	3/27/05 3:25	3:30	34	3/27/05 9:59	10:00	26	Yes	No
20	3/28/05 8:41	8:45	24	3/28/05 11:12	11:15	19	No	Yes
21	3/28/05 23:02	23:00	22	3/29/05 1:10	1:15	23	No	Yes
22	3/29/05 4:24	4:15	32	3/29/05 4:52	5:00	20	Yes	Yes
23	4/12/05 7:19	7:15	19	4/12/05 7:29	7:30	21	No	Yes
24	4/12/05 9:40	9:45	29	4/12/05 10:20	10:30	18	No	Yes
25	4/12/05 17:30	17:45	36	4/12/05 17:50	18:00	26	Yes	No
26	4/16/05 1:23	1:15	32	4/16/05 3:13	3:30	18	Yes	Yes
27	4/16/05 5:24	5:15	30	4/16/05 5:34	5:45	29	Yes	No
28	4/16/05 6:54	6:45	24	4/16/05 7:04	7:30	17	No	Yes
29	4/23/05 3:22	3:15	29	4/23/05 4:12	4:15	27	No	No
30	5/18/05 11:22	11:30	31	5/18/05 12:42	12:45	35	Yes	No
31	5/18/05 14:42	14:45	28	5/18/05 15:02	15:00		No	
32	5/18/05 15:22	15:30		5/18/05 15:52	16:00	24		Yes
31-32								
33	5/19/05 2:13	2:15	29	5/19/05 3:33	3:30	23	No	Yes
34	5/21/05 16:25	16:30	33	5/21/05 16:35	16:45	28	Yes	No
35	5/21/05 18:15	18:15	27	5/21/05 19:35	18:45	27	No	No
36	6/5/05 10:36	10:30	18	6/5/05 10:46	10:45	21	No	Yes
						% Verified	57.42	53.57

Note: The rows shaded in same color represent were determined to be part of one continuous high wind event

6.3. Maintenance History

Initially the activation thresholds were based on gust speeds; however, maintenance personnel found that the activations and deactivations of the systems were too sensitive to overcome the variation due to the tumultuous nature of winds on the southern Oregon coast. Therefore, ODOT ITS Unit design engineers changed the activation and deactivation logic to be based on the 2-minute average wind speeds measured by the anemometer. The maintenance staff survey after the automation of these systems (Appendix F) shows that the system works very accurately and effectively in the view of the interviewed maintenance staff. The South Coast system was recently updated to notify the TOC of system activation and deactivation.

The Yaquina Bay Bridge system has had one instance of fuses on the radio and the network circuit not functioning very well. The systems have been functioning well except for this one instance.

6.4. Summary

This chapter sought to analyze the effectiveness of the technology used in the AWWS. An assessment of these systems using the available data from the nearest weather stations show promising results, even though the wind speeds measured at these locations are expected to be very different from the ones measured by the AWWSs. The systems have needed very minimal maintenance from January 2004 after they have been fully automated.

7. OPERATIONS ASSESSMENT

One motivation for ODOT implementing these AWWS is to automate and expedite the process of activating the warning signs to alert highway users when high winds are detected. Through expediting activation of the flashing beacons, these systems are expected to provide operational savings to ODOT and the traveling public.

This chapter presents an assessment of the direct and indirect benefits of AWWS in terms of traffic control and operations along US Route 101. These are important pieces to evaluate the economic savings resulting from these systems. The operational cost savings include direct cost savings from not having to use a maintenance crew and highway patrol officers outside of normal hours, and indirect cost savings by not having to close the roadway totally but still providing adequate warning to drivers.

This chapter first presents how implementation of the AWWS changed highway operations in each location. The remainder of this chapter derives the benefits and costs associated with these systems. More details on this assessment can be found in Technical Memorandum 2 (15).

7.1. Operations

Maintenance personnel responsible for both these systems and the ODOT personnel who developed these systems were interviewed as to the motivation for automating these systems (See Appendix E for more details). Maintenance personnel at both locations said that the system was installed to protect their personnel from working outside of their vehicles when high winds are present.

7.1.1. Before AWWS (Base Case)

To assess the operational changes resulting from automating the wind warning process, it is important to define the base case – i.e. how high winds events were handled before the advent of the AWWS.

South Coast System

The 27-mile stretch of US Route 101 between Port Orford and Gold Beach experiences high cross winds frequently between November and May. There are no major diversion routes or rest areas available on this stretch of highway. This makes it necessary to warn drivers of a high cross winds hazard before they enter this stretch of highway so that they can choose to stay in one of the nearby towns until the winds subside or to decide to proceed with caution. A crash in this stretch of highway will effectively close down the road for extended periods of time. Maintenance personnel stated that the typical road closures due to high cross winds lasted between four and eight hours before the AWWS was installed.

Prior to the AWWS, when maintenance personnel were notified of high wind conditions along this corridor – either from the public through telephone calls or through observation of wind speeds during their regular field maintenance activities – a maintenance crew would take a vehicle mounted with an anemometer to the field to measure the wind speeds. If the wind speeds were measured to be higher than 40 mph for a sustained time period, the maintenance crew would call the highway patrol and coordinate a road closure. Two maintenance personnel (one for each side) were required to be on-site, along with highway patrol officers, to help stop traffic. Maintenance personnel would monitor high winds until they subsided to a level where the road could be safely opened. In general, these high winds events last from four to eight hours.

Yaquina Bay Bridge System

It was noted by maintenance personnel that the Yaquina Bay Bridge on US Route 101 provides a vital link for traffic in and through Oregon along the Pacific coast. When the bridge is closed, vehicles must take an alternate route that is about 20 miles longer and is not designed to handle the additional traffic. This situation makes it important that the bridge stays open as well as safe for traffic. Crashes that occur on the bridge can lead to bridge closures between four and eight hours, thus leading to numerous hours of delay. This automated system was expected not only to eliminate the need for maintenance personnel to travel to and on the bridge to switch on the signs, but to expedite wind warnings to high-profile vehicles. This would prompt drivers of high-profile vehicles to wait out high-speed winds and gusts, rather than getting caught in a potentially dangerous situation.

The base case for the Yaquina Bay Bridge is identical to that of the South Coast System. Road closures were also used here, as the bridge acts as a critical link for area motorists.

7.1.2. With AWWS

This section summarizes the operation of each system as implemented. More details on these operations were provided in Section 6.1.

South Coast System

When a high wind event (wind speeds > 35 mph) is detected automatically via anemometer readings, the controller at the Humbug Mountain RWIS dials the controllers at the Port Orford and Gold Beach (Wedderburn) locations. These controllers at the sign locations turn the beacons on. Maintenance personnel are therefore not directly involved, unless a road closure is necessary because of exceptionally severe weather, a crash blocking the roadway, or other factors. Wind speeds are monitored continuously and the signs are deactivated when the average wind speeds over a two-minute time period fall below 25 mph.

Yaquina Bay Bridge System

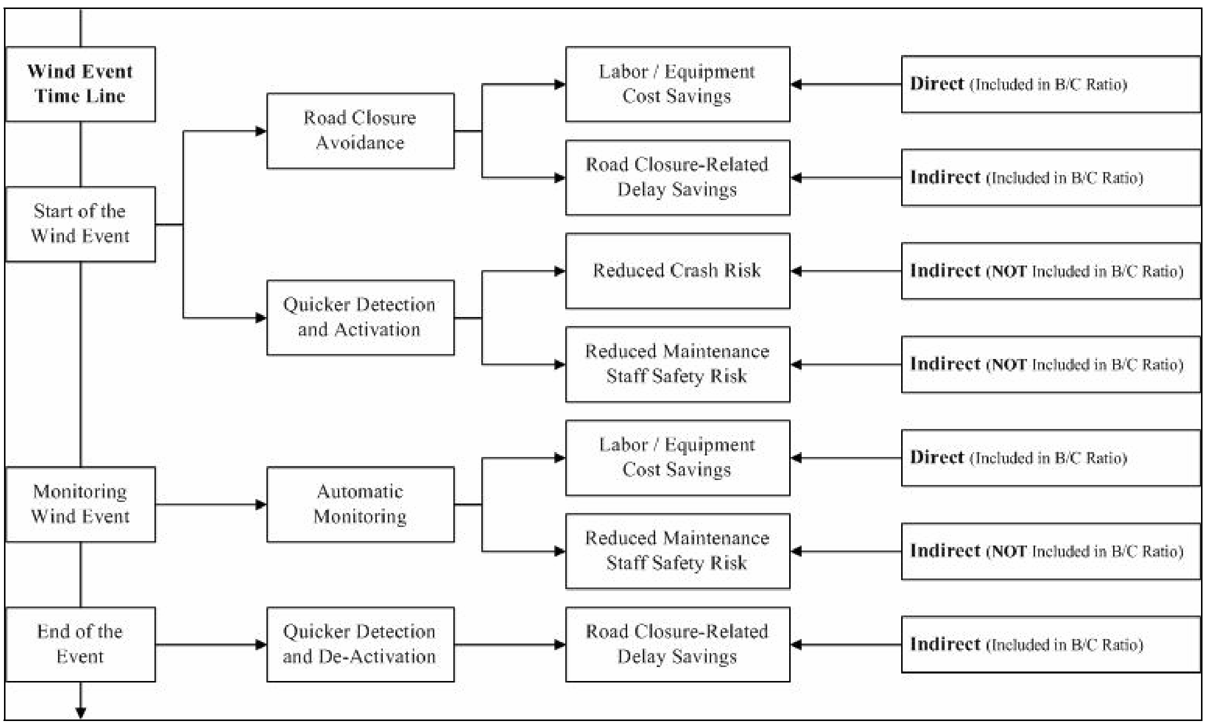
When a high wind event (wind speeds > 35 mph) is detected, the controller at the bridge dials the controllers at the signs on both ends of the bridge. These controllers at the signs turn the beacons on. The controller attached to the anemometer then notifies the Traffic Operations Center in Salem that the signs are activated. Maintenance personnel are only sent out to close the roads when the wind speeds reach higher than 80 mph. Wind speeds are monitored continuously at regular intervals and the signs are deactivated when the average wind speeds over a two-minute time period fall below 25 mph.

7.2. System Benefits

As mentioned earlier, the operational benefits of the AWWS are both direct and indirect. The direct benefits include the labor and equipment cost savings realized by not having maintenance personnel and state police on-site during wind events to enact road closures. Delay reductions due to automation of activation and deactivation and reduced safety risk for the driving public and maintenance staff are considered indirect benefits for the purpose of this study.

Figure 7-1 shows how the different benefits from using an AWWS – in comparison to the base case – correspond to different points in a high wind event. This breakdown will be used to calculate the benefits of the system. As can be seen, some potential benefits of the system are not included in the benefit-cost calculation because of the high number of assumptions that would need to be made.

Figure 7-1: Schematic Diagram of Direct and Indirect Benefits of AWWS



7.2.1. Direct Benefits

As was shown in Figure 7-1, the direct benefits of the AWWS result from labor and equipment cost savings realized through avoiding road closures and the need to manually monitor conditions (on-site) during high-wind events at regular intervals. In both cases, annual savings are a function of the number of high-wind events observed at each site.

Activation records of the AWWS between Port Orford and Gold Beach (South Coast system) shows five instances of activation for an average duration of 14 hours and 47 minutes between

February and May of 2002 (see Technical Memorandum 2 for more details). It should be noted that these five activations were recorded only over half of a typical high winds season. Maintenance personnel estimate that they would normally have had to close down this section of highway between five and ten times per year because of high winds prior to installation of the AWWS at South Coast. The records of actual activations of the AWWS seem to corroborate these estimates. Since sign activation records were archived only starting April 2005, maintenance personnel's estimate of average road closure duration – between four and eight hours – is used.

For the Yaquina Bay Bridge, maintenance personnel estimated that the bridge would be closed due to high winds about thirty (30) times per year prior to installation of AWWS at Yaquina Bay Bridge. The average duration of sign activation between December 2004 and June 2005 for Yaquina Bay Bridge system is about 2.5 hours. The average duration was calculated after combining events within 30 minutes of each other (i.e. the start time of an event is within 30 minutes of the end time of the next event). More recent records of the sign activations show that the longest events were 16 hours and 2½ hours long for the Yaquina Bay Bridge and South Coast systems, respectively.

Based on the average durations of road closures – four hours for the South Coast system and two and half hours for the Yaquina Bay Bridge system – and the average distances between the maintenance yards and the system locations, the average labor and vehicle costs per closure and for an average year are shown in Table 7-1. The labor rates were calculated from prevailing wage rates published by the Oregon Bureau of Labor and Industries. To be conservative in the overall estimation of savings, the rates used here are base rates, not overtime rates. Wind-related road closures that occur during overtime periods such as nights or weekends would therefore have higher labor costs (perhaps 50 percent higher). The number of work hours is estimated by adding the driving time to the average road closure time. Distances are one-way for ODOT or OSP personnel to travel to the site from their local office. It is assumed that ODOT crews would go to the site each hour during the wind event (i.e. one round-trip per hour), whereas OSP officers would stay on-site until the closure ended. The number of closures per year is estimated at 5 to 10 for the South Coast system (although a crew would need to be called to monitor conditions ten times per year) and 30 for Yaquina Bay. The estimation of the direct cost savings from labor and equipment did not include any special equipment other than the vehicles for the maintenance staff that may be needed to transport road blocks and such.

Table 7-1: Labor and Equipment Cost Savings

	South Coast		Yaquina Bay Bridge	
Cost Category	Per Closure	Per Year	Per Closure	Per Year
ODOT Maintenance Crew				
Personnel				
Number of Crew Members	3	30	3	90
Work Hours	6	60	3.5	105
Labor Cost (@ $33.47 average wage)	$ 603	$ 6,030	$ 351	$ 10,530
Vehicle Operations				
Number of Vehicles	2	20	2	60
Miles Driven	4	40	3	90
Vehicle Cost (@ $0.50/mile)	$ 32	$ 320	$ 18	$ 540
Oregon State Police				
Personnel				
Number of Crew Members	2	20	2	60
Work Hours	6	60	3.5	105
Labor Cost (@ $32.01 average wage)	$ 384	$ 3,840	$ 224	$ 6,720
Vehicle Operations				
Number of Vehicles	2	20	2	60
Miles Driven	4	40	2	60
Vehicle Cost (@ $0.50/mile)	$ 8	$ 80	$ 4	$ 120
Total Labor and Equipment Cost Savings	**$ 1,027**	**$ 10,270**	**$ 597**	**$ 17,910**

7.2.2. Indirect Benefits

Of the indirect benefits identified in Figure 7-1, only those associated with delay savings related to road closures are included in this analysis. There are two types of delay savings that would be realized from the AWWS. First, road closures are not automatically enacted when high winds occur, which means that delay will be reduced for motorists when the road can be kept open. Second, for those occasions when a road closure is required, the automated system will allow for quicker removal of the closure when winds subside.

In both cases, the estimated delay associated with road closures is based on traffic characteristics associated with each location. Traffic volumes used in estimating delay savings are derived in Table 7-2. Traffic volumes are estimated based on average duration wind events (6 hours for South Coast, 2 ½ hours for Yaquina Bay). Two volume scenarios are presented: an average volume scenario which assumes the closure may happen at any time of the day, and a high volume scenario, which includes the 30th highest hour volume as the volume during one hour of the closure. It is possible that a certain percentage of motorists choose to take an alternate route during high-wind events. An estimation of the percentage of drivers that may choose to take an alternate route was performed based on the responses to the motorist survey conducted for the two locations in Oregon (16). The traffic characteristics of these two system locations are elaborated in Technical Memorandum 2 (15).

Table 7-2: Traffic Volumes Used in Delay Estimation

	South Coast		Yaquina Bay	
	Average	High	Average	High
Location				
ADT Measurement	0.3 miles south of Port Orford		US Route 101/25th Street in Newport	
Classification Count	1.1 miles north of state line		US Route 101/25th Street in Newport	
Daily Traffic				
Annual Average Daily Traffic (AADT)	2,940		19,294	
Wind Season* ADT divided by AADT	0.794		0.882	
% Trucks	8.7%		5.1%	
30th Highest Hour Volume	*547*		*2,335*	
Affected Traffic Volume				
During Road Closure				
Total	584	1,033	1,773	3,399
Cars	533	943	1,683	3,226
Trucks	51	90	90	173
% Waits Through Closure				
Cars	73.9%		71.6%	
Trucks	71.7%		75.7%	
Vehicles Wait Through Closure	431	762	1,273	2,441
Cars	394	697	1,205	2,310
Trucks	37	65	68	131

* - Wind season includes January, February, March, November and December.

South Coast System

For an average six-hour road closure between Port Orford and Gold Beach, it is estimated that 26.1 percent of the motorists and 28.3 percent of high profile vehicles will take an alternate route or wait for the winds to subside when the AWWS is activated. Table 7-3 shows the average delay and cost associated with the delay due to a road closure. To be conservative, the average volume scenario is used for calculating benefit-to-cost ratios. The value of time is a critical parameter for estimation of benefits and costs, and there is significant variability in the estimated value of time across different studies. For example, an evaluation of Oregon's Operation GreenLight program estimated the value of time for commercial vehicles to be about $1.24 per minute (i.e. $74.40 per hour) (17). The estimation based on the Federal Highway Administration's (FHWA) HERS model was found to be more applicable for this analysis, and so it was used. The value of truck travel per hour using the HERS model is estimated to be $27.83 in 2003 U.S. dollars. The value of time for all employees is estimated to be $18.56 per hour based on average wage rate from National Income and Product Accounts (NIPA) of the United States, for 2000 (18).

Table 7-3: Average Delay Costs per Road Closure (South Coast)

Average Delay per Closure	Average Volume Scenario	High Volume Scenario
Passenger Vehicles		
Vehicles Delayed per Closure	394	697
Average Value of Time per Hour	$18.56	$18.56
Average Cost	$7,313	$12,936
Heavy Trucks		
Trucks Delayed per Closure	37	65
Average Value of Time per Hour	$27.83	$27.83
Average Cost	$1,030	$1,809
Average Cost of Delay Per Closure	**$8,343**	**$14,745**

Without the AWWS, ODOT would have to close the roadway when the high winds reach speeds of 80 mph. If the roads are still closed during these high wind events, there are not any delay savings. To account for this, the number of road closures avoided by the implementation of AWWS is estimated to be five. For the five avoided road closures, the average annual cost savings due to road closures between Port Orford and Gold Beach would be between $41,715 and $73,725 per year. Savings under high volume scenarios would be higher.

Apart from the benefits discussed above, there are also savings from informing drivers of high wind conditions more promptly. Motorists who choose to wait out the winds when the AWWS is activated would start waiting earlier as they are notified earlier through the automated systems compared to a manually operated warning. At the same time, the waiting motorists will be notified of the cessation of high wind conditions earlier through the automated system compared to manually operated warning as the maintenance personnel only measure the wind speeds at regular intervals (e.g. one- or two-hour intervals). This quicker notification will lead to a reduction in the safety risk of the motorists and may also lead to a reduction in their wait time. Table 7-4 shows the average delay savings from the system for drivers who choose to wait out the high winds as opposed to taking an alternative route. Estimated savings are calculated based on how much more quickly the deactivation can result in re-opening the road. For purposes of calculating the benefit-cost ratio, it was assumed that the system would reduce delay by 20 percent through more prompt deactivation of wind warnings.

Table 7-4: Average Delay Savings for Stopped or Diverted Traffic per Wind Event (South Coast)

	Average Volume Scenario	High Volume Scenario
Stopped or Diverted Passenger Vehicles	139	246
Average Cost of Delay for Drivers per Closure	$2,582	$4,567
Estimated Savings from		
10% Reduction in Delay (36 min)	$258	$457
20% Reduction in Delay (72 min)	$516	$913
30% Reduction in Delay (108 min)	$775	$1,370
40% Reduction in Delay (144 min)	$1,033	$1,827
Stopped or Diverted Truckers	14	26
Average Cost of Delay for Truckers per Closure	$401	$710
Estimated Savings from		
10% Reduction in Delay (36 min)	$40	$71
20% Reduction in Delay (72 min)	$80	$142
30% Reduction in Delay (108 min)	$120	$213
40% Reduction in Delay (144 min)	$161	$284

As estimated earlier, the number of activations of the signs for extended periods of time is about five times per year during the high winds season (i.e. not including the road closure events). The savings for the drivers that choose to wait out the high winds or take an alternate route is between $2,580 and $4,565 per year. The savings from the automation of the signs attributable to reducing delays for truckers over one year could range between $400 and $710 per year.

Yaquina Bay Bridge System

Table 7-5 shows the average delay and cost associated with an average two and half-hour closure at Yaquina Bay Bridge. It was estimated that 28.4 percent of the motorists and 24.3 percent of the truckers will choose to pullover and wait or take an alternate route when the AWWS is activated from the motorist survey results for Yaquina Bay Bridge system.

Table 7-5: Average Delay Costs per Road Closure (Yaquina Bay Bridge)

Average Delay per Year	Average Volume Scenario	High Volume Scenario
Passenger Vehicles		
Average Number Delayed per Closure	1,205	2,310
Average Value of Time per Hour	$18.56	$18.56
Average Annual Cost	$22,365	$42,874
Heavy Trucks		
Average Number Delayed per Closure	68	131
Average Value of Time per Hour	$27.83	$27.83
Average Annual Cost	$1,892	$3,646
Average Cost of Delay Per Closure	**$24,257**	**$46,520**

As indicated by maintenance personnel when they were interviewed, there were up to 30 bridge closures per year before the installation of AWWS.

Based on the recollection of maintenance personnel during interviews and available weather data, it is estimated that sustained high winds of speeds more than 80 mph for extended time periods occur about 20 times a year. Without the AWWS, ODOT would close the bridge when high winds reach speeds of 35 mph. Even with the AWWS, ODOT still closes the roadways when the wind speeds exceed 80 mph. Based on this information, it can be assumed that the difference in the number of bridge closures since installation of AWWS (i.e. the wind speeds being between 35 mph and 80 mph) is about ten instances per year. Based on these assumptions, the total annual average costs due to the bridge closures would have been between $242,570 and $465,200 per year (i.e. for 10 bridge closures per year). In the more recent interview of the maintenance personnel, it was indicated that there may be about one road closure every two years due to wind speeds above 80 mph.

Table 7-6 shows the average delay savings from automation of the system for the vehicles, including high profile vehicles that choose to wait out the high winds. For the purposes of calculating benefits, it was again assumed that the AWWS would allow the bridge to re-open to traffic 30 minutes earlier.

Table 7-6: Average Delay Savings for Stopped or Diverted Traffic per Wind Event (Yaquina Bay Bridge)

	Average Volume Scenario	High Volume Scenario
Stopped or Diverted Passenger Cars per Event	478	916
Average Cost of Delay for Drivers per Closure	$8,869	$17,003
Estimated Savings from		
10% Reduction in Delay (15 min)	$887	$1,700
20% Reduction in Delay (30 min)	$1,774	$3,401
30% Reduction in Delay (45 min)	$2,661	$5,101
40% Reduction in Delay (60 min)	$3,548	$6,801
Stopped or Diverted Truckers per Event	22	42
Average Cost of Delay for Truckers per Closure	$612	$1,172
Estimated Savings from		
10% Reduction in Delay (15 min)	$61	$117
20% Reduction in Delay (30 min)	$122	$234
30% Reduction in Delay (45 min)	$183	$352
40% Reduction in Delay (60 min)	$245	$469

As estimated earlier, the number of activations of the signs for extended periods of time is about 10 times per year during the high winds season excluding road closures due to wind speeds of 80 mph or more. The savings for the drivers that choose to wait out the high winds is between $17,740 and $34,010 per year. The savings from the automation of the signs imputable to reducing delays for truckers over one year could range between $1,220 and $2,340 per year.

7.2.3. Other Indirect Benefits

For completeness, it is important to note the other potential indirect benefits of the AWWS. While these benefits are not quantified in the benefit-cost analysis, they should be acknowledged as a part of the overall system effectiveness.

Safety Benefit

With a more reliable and prompt wind warning, fewer vehicles will be exposed to high wind events, which consequently should improve crash risk. Crashes at either location could result in a road closure, causing significant delay. The relatively infrequent number of wind-influenced crashes at each location would require a significant number of assumptions in order to estimate potential safety benefits attributable to AWWS. The Oregon crash report form does not have high winds listed as a contributing factor. This makes it even more difficult to measure the safety benefits of AWWS at these two locations.

With some basic assumptions, the safety benefits associated with reducing crashes appear small, because of the relative infrequency of wind-related crashes. The average crash rates over the wind season (i.e. November to March) are estimated to be 0.67 and 1.27 crashes per million vehicle miles of travel (VMT) for the South Coast and Yaquina Bay Bridge systems, respectively, based on crash data for years between 1997 and 2003. The annual average crash rates are estimated to be between 0.57 and 0.75 per million VMT for the South Coast and Yaquina Bay Bridge locations, respectively, averaged over the same time period. Using these crash rates, it was determined that the reduction in crash exposure for the driving public from one less hour of exposure to traffic during high wind months because of more prompt sign activation would be 0.0017 crashes per hour and 0.00037 crashes per hour for South Coast system and Yaquina Bay Bridge system, respectively. In other words, it would take hundreds or thousands of high-wind events for the earlier system activation to reduce the expected number of crashes by even one at either location. In both locations, however, a single crash will not only affect the safety of people directly involved in the crash, but will also likely close the road, causing potentially significant delays. These benefits are real, but are not quantified because of the numerous assumptions required.

Reduced Risk for Maintenance Personnel

Maintenance personnel could be susceptible to a greater risk of injury when exposed to high-wind events. The relatively infrequent number of injuries to maintenance personnel would make it difficult to precisely estimate the potential benefits in this area.

Reliability and Customer Satisfaction

Automation of the systems has led to better customer satisfaction and also a better perception of the reliability of the warning system. A better perception of reliability leads to better adherence to the advisory warning message that can potentially result in safer driving conditions and reduced overall delay for everyone.

7.3. System Costs

The implementation costs were estimated to be approximately $90,000 for both the systems. The annual maintenance costs of the South Coast and Yaquina Bay Bridge systems are expected to be $3,000 and $3,500 per year, respectively. These costs were estimated costs as the systems were designed, built and installed by ODOT, and numerous state resources were used in the processes that were not readily traceable. Maintenance cost estimates are based on another COATS Showcase study on maintenance costs of field elements in rural areas. These costs are broken down in Table 7-7.

Table 7-7: System Implementation and Maintenance Costs

	Implementation Costs	Annual Costs (Recurring) Maintenance	Operational	Total
South Coast System	$90,000	$1,500	$1,500	$3,000
Yaquina Bay System	$90,000	$1,500	$2,000	$3,500

7.4. Benefit-Cost Ratio

The identified costs and benefits in the previous sections of this document were used to calculate the benefit-to-cost ratio presented in this section. The following assumptions were made for this estimation.

1. A ten-year analysis period was used for the calculation of benefit-to-cost ratio.
2. A traffic growth rate of 2 percent per year and a rate of return (ROR) of 7 percent are assumed.
3. 3 percent inflation is assumed to calculate the benefits in 2004 US dollars.

The benefit-cost ratio calculations, and the number of years until the benefits exceed the costs (break even analysis), are shown in Table 7-8.

Table 7-8: Benefit-Cost Calculations

	South Coast		Yaquina Bay Bridge	
	Average*	High**	Average*	High**
Number of Closures per Year	*5*	*10*	*20*	*30*
Benefits				
Direct Savings from Non-Closure	$ 5,135	$ 10,270	$ 11,940	$ 17,910
Delay Reductions from Non-Closure	$ 41,715	$ 73,725	$ 242,570	$ 465,200
Delay Reductions from Quicker Deactivation	$ 2,980	$ 5,275	$ 18,960	$ 36,350
Costs				
Initial Installation Costs (non-recurring)	$90,000		$90,000	
Power, Communiation and Maintenance (recurring)	$3,000		$3,500	
*B/C Ratio****				
Direct Benefits Alone	0.87		1.46	
Direct and Indirect Benefits	4.13		22.80	
Number of Years Before Benefits Exceed Costs				
Direct Benefits Alone	12 years		7 years	
Direct and Indirect Benefits	3 years		1 year	

* - "Average" scenario includes average number of wind events and average traffic volumes
** - "High" scenario includes high number of wind events and high traffic volumes
*** - B/C ratio is calculated based on "average" benefits

The estimated benefit-cost ratios indicate that both AWWS in Oregon will result in direct returns equal to their installation and recurring maintenance and operations costs to ODOT equal to the cost of installation and annual maintenance within 12 years for the South Coast system and 7 years for the Yaquina Bay Bridge system. If delay reductions to the motorists are considered, the benefits of the system pay for the system installation and maintenance costs within two years for the South Coast system and one year for the Yaquina Bay Bridge system. As was stated earlier, these benefit-cost ratio estimates did not include any indirect benefits such as improved safety for maintenance personnel and improved safety for the motorists during high wind events. Higher benefits from Yaquina Bay bridge system can be attributed to the facts that the Yaquina Bay Bridge experiences high cross winds more frequently than the South Coast system location, and that traffic volumes through the Yaquina Bay Bridge are much higher than through the South Coast location.

7.5. Summary

It can be concluded that these AWWS deployments offer significant cost savings to drivers as well as ODOT. These systems also allow more prompt high wind notifications to the drivers thus reducing exposure of the driving public to high cross winds along US Route 101.

It should be noted that the direct benefits from the two AWWS systems in Oregon would exceed their installation, operational and maintenance costs between seven and twelve years after installation, depending on the frequency of road closures related to high wind events and the traffic volume through these locations.

8. SUMMARY AND RECOMMENDATIONS

US Route 101 is a very important corridor for the movement of freight and tourists and it is critical to keep this highway open. ODOT ITS Unit designed and deployed automated wind warning systems (AWWS) to reduce the number of road closures on US Route 101 and improve efficiency. This evaluation has examined these systems regarding their effectiveness in terms of their planned objectives. Measures of effectiveness (MOEs) were determined based on the system objectives and used for the evaluation of the AWWSs in Oregon. Six MOEs were chosen as the focus of this evaluation:

1. Reduction in wind induced accident frequency and severity
2. Traveler awareness of these systems
3. Traveler perception of the usefulness of these systems
4. Traveler perception of the reliability of the system
5. System accuracy
6. Operational cost savings.

MOE 1 was measured through an analysis of crash data for the years 1997-2003. MOEs 2 through 5 were reviewed in the motorist survey results. MOE 5 was also measured through the technology assessment. MOE 6 was quantified through the operational assessment.

8.1. Summary of Evaluation Findings

Analysis of crash data between 1997 and 2003 shows that there is a statistically significant difference between the crash rates in high wind season (i.e. November to March) and the crash rates in the non-high wind season (i.e. the remaining months). The system has been fully automated only for part of one high wind season (December 2003 – March 2004) and the crash data for 2004 does not show a statistically significant change in crash rates. It should be noted that there have always been some form of warning for high winds at these two locations and this comparison of crash rates is not a comparison of “no warning” and “automated warning”. This made a before-after comparision of crash rates impossible. An attempt to determine MOE 1 for these two system locations as shown in Chapter 4 found that there is a potential to reducing the number of crashes by reducing the exposure of high speed traffic to high cross winds.

From the results of the motorist survey, it is determined that 84 percent of the respondents for the South Coast system and 86 percent of the respondents for the Yaquina Bay system who have driven through the location during high cross winds have seen the beacons flashing (i.e. MOE 2). The response to the statement, “This system would provide me with useful information” received the highest average rating (4.26 and 4.18 for South Coast and Yaquina Bay Bridge systems, respectively) on the ordinal scale of 1-to-5 (MOE 3). Eighty-four percent of the respondents for the South Coast system and 80 percent of respondents for Yaquina Bay system either “strongly agree” or “agree” that the system will provide them accurate information on high winds (MOE 4 and 5).

Surveys of maintenance staff after the automation of these systems (Appendix F) shows that the systems work accurately and effectively. The Theory of Operations (TOO) diagrams shown in

Chapter 6 show that the systems are well designed to account for all scenarios for automated activation and deactivation of the warning messages. An assessment of these systems using the available data from the nearest weather stations shows promising results even though the wind speeds measured at these locations are expected to be very different from the ones measured by the AWWSs (MOE 5).

The estimated benefit-cost ratios indicate that both AWWS in Oregon will result in direct returns equal to their installation and recurring maintenance and operations costs to ODOT within 12 years for the South Coast system and 7 years for the Yaquina Bay Bridge system. If delay reductions to the motorists are considered, the benefits of the system pay for the installation and maintenance costs within two years for the South Coast system and one year for the Yaquina Bay Bridge system (MOE 6). Overall, the system has performed between "very well" and "somewhat well" on all of the six MOEs.

8.2. Recommendations

Based on the safety analysis, it may be concluded that most of the wind-related crashes involve single vehicle or run-off-the-road type of crashes. It may also be interpreted that most of the wind-related crashes are caused by drivers caught in high cross winds unexpectedly. A high wind warning system that is automated helps warn the drivers in time and reduce the crash risk exposure. The use of the system to warn drivers in advance of their entering highway sections with high cross winds helps them choose not to enter the highway and wait out the high winds or take an alternate route, if available. The AWWS activation messages may be broadcast over a HAR also, so if the drivers choose to wait in a nearby rest area, they may still be able to know whether the high winds are present even if the signs are not visible. Since the 511 traveler information telephone number is fully operational in Oregon, it may be useful for US Route 101 travelers to provide warnings in this way as well.

A significant number of motorists (about 80 percent of respondents for both systems) agreed that it would be useful if the wind speeds are also posted. ODOT may consider upgrading these systems to be able to post wind speeds (e.g. with the use of VMS) when the funds are available. Other locations in the state that have frequent occurrences of high wind events (i.e. about 10 or more occurrences of road closures due to high winds) may be considered for further deployments of AWWS as the system is shown to have direct benefits to ODOT exceeding the total costs including operations and maintenance costs within 12 years depending on the traffic volume through the identified location.

This research provides clear implications regarding potential countermeasures for wind-influenced crashes. Transportation agencies have used a variety of treatments to deal with these crashes over the years. It appears that dynamic information systems and spot design improvements to address run-off-the-road and hit object crashes both have good potential to improve safety at locations where wind-influenced crashes are more frequent.

8.3. Future Research

The AWWS on Interstate 5 in California is expected to be fully automated and operational in the next year. This system will use a CMS to notify drivers of high wind events. It will be useful to conduct a subsequent evaluation of this system to determine the comparative benefits and dis-benefits of using CMS as opposed to flashing beacons on top a static warning sign as the driver information component of the AWWS. Though both notification methods are considered active, it is expected that there will still be differences in the user perception and the acceptance of warning messages on CMS compared to flashing beacons. The road closures on Interstate 5 due to high winds are also not as frequent as the other two systems in Oregon. This will influence the benefit-to-cost ratio of this system.

A subsequent crash analysis may be performed after additional one or two years of post-installation data for the two AWWS locations in Oregon. This may help assess the MOE 1 (i.e. the reduction in wind induced accident frequency and severity) in this evaluation with better statistical confidence. The crash reporting system may also be researched further to examine the inclusion of wind as an option in the set of contributing factors.

Benefits of automation of these signs are shown to exceed the costs of automation in a reasonable period of time. Other manual procedures related to activation and deactivation of warning messages or road closures may be further investigated to determine whether they can be automated with acceptable accuracy, and whether the benefits would outweigh the costs.

APPENDIX A: MOTORIST SURVEY DATA COLLECTION PLAN

The purpose of the motorist survey is to gauge the subjective responses of motorists to the wind warning systems. Motorists will be surveyed to determine the perceived benefits and effectiveness of the system. This survey should address questions concerning whether motorists noticed the signage, whether they considered the information accurate and/or useful, and what effect they felt it had on their behavior. This survey may provide a "reality check" as to the value of providing dynamic information compared to static signage. Because of the differences between the Oregon and California systems, this may also provide an indicator of how wind warning information is best conveyed.

The first step in survey development is to develop a data collection plan. This data collection plan identifies the relevant population and desired sample size, recommends preferred methods of survey distribution, and outlines key areas of inquiry in the survey, and addresses other areas needed to conduct the survey. It may be necessary to target specific sub-populations, including commercial vehicle operators and recreational vehicle drivers, in order to ensure that all motorists are adequately represented in the survey responses. Since the survey will be distributed after all systems are active, the survey will be constructed with some attempt to measure how motorists would have responded or would have perceived the roadway without the system in place.

Scope and Extent of Survey

Guidelines for this section were developed in consultation with the Institute of Transportation Engineers' Manual of Transportation Engineering Studies (19).

- Time periods. The survey will be conducted during Spring 2004. High winds are prevalent between the months of November through March. Surveys would be conducted between March and May, when the hazards of driving during high crosswinds conditions would be fresh in the minds of respondents.

- Target population. The population of interest is motorists who drive through the system locations during high cross-winds. This would include both local and out-of-state users, commercial vehicle drivers and passenger car drivers, commuters and tourists. The survey should focus on drivers, not on passengers.

- Type of responses. Surveys may use written or verbal responses from a sample of people. Verbal responses may be gathered through personal interviews or telephone interviews. In order to economize on the time spent in data collection and processing, a survey using written responses would be preferred for this project.

Common methods of collecting written responses include a form sent and returned by mail, a form distributed in person and returned by mail, and a form distributed and returned in person. A survey form may also be distributed through email lists and the responses could be collected online.

Survey Distribution Method

In-Person Distribution Method

Ideally, the best method for reaching the target population for this study would be to intercept all vehicles that pass through these locations in both directions during specific time periods and hand over the survey forms. The forms can also be handed over at points where vehicles are already stopped – e.g. rest areas, traffic signals, and gas stations. Targeting vehicles that are already stopped would be logistically easier. It is doubtful that there would be enough traffic to generate a meaningful and a true representative sample in either rest areas or gas stations. At traffic signals, there would be concerns about safety of the survey crew.

There are other options for stopping traffic. One is to literally stop traffic on the roadway, through the usage of temporary signage, traffic cones, and the presence of law enforcement personnel and vehicles. Vehicles would be stopped, given a survey packet with a brief verbal explanation, and then allowed to proceed. This could take perhaps 15 seconds per vehicle, which may be reduced depending upon the type of signage used in advance of the survey distribution point. This method can work well on roadways where traffic volumes are fairly small. If queue lengths get unacceptably long, the survey distribution can stop and vehicles can pass unimpeded through the work zone until the queue is emptied. This method does have disadvantages as well. It would work poorly for traffic at night, when traffic volumes are lower and motorists are not anticipating work zone-type activity. To economize on costs, it would probably be necessary to limit the survey to one day per location, which may reduce the ability to get a good sample of both commuter and tourist traffic. There are also concerns over crew safety, especially if surveys are conducted during high cross winds conditions, and it is also necessary for high patrol to be involved to make the traffic stop successful (OHP and CHP).

The traffic through the location on Interstate 5 is mostly long distance travelers. The best way to reach them is in-person distribution of survey forms. The agriculture inspection station near the system on Interstate 5 can be used for this purpose as the point where the surveys can be handed out and asked to be mailed back. It is expected that it would be a good place to hand out the surveys as all vehicles stop here and the sample will be very representative of the driving population of this system location. The drawback in using this method is that travelers are being alerted of this system before they go through this corridor. This may skew the results of the survey.

The following combined approach is suggested for the Interstate 5 system in California. The long-distance motorists could be surveyed by handing out a mailback survey form at the Weed Safety Roadside Rest area and handing out the survey forms at the Ashland Point of Entry could capture the truckers. Distributing the survey forms to local residents through mail could serve well for surveying the commuter population of the traffic.

From the site review, it is understood that the traffic through the two locations on US Route 101 are typically the local commuters and truckers based in Oregon. This will be verified with the responsible traffic engineers. If this is determined to be accurate, the survey forms will be distributed through mail to the local residents to get the input from the motorists. The addresses for the local residents would be obtained from an online resource named www.infousa.com . The survey forms to the truckers would be distributed through the Oregon Truckers Association.

Mail Distribution Method

Instead of distributing the surveys in-person, the surveys may be distributed by mail. The most effective method for doing this would be to record license plates of vehicles passing these three locations, and then mail surveys to addresses based on the registration of vehicle owners. This could be done safely and cost-effectively using video cameras to record license plate information. There are several concerns with this method. First, there may be legal issues that would prevent the research team from obtaining vehicle registration addresses from observed license plates, not only in California and Oregon but also for motorists from other states. Second, for some vehicles, especially commercial vehicles, the same license plate may be used by a variety of drivers over time, so that the respondent may not be the motorist who drove through the location.

Alternatively, one may attempt to construct a mailing list that may be representative of the kinds of motorists who tend to cross these three locations. To do this requires some knowledge of what the target population is. Based primarily on anecdotal evidence, here are some of the characteristics of traffic at these three specific locations.

- According to Caltrans maintenance staff, more than 40 percent of traffic through Yreka and Weed is commercial vehicle traffic.

- The traffic through the South Coast system is predominantly local commuters from Port Orford to Gold Beach and Brookings to Port Orford.

- Commercial vehicle traffic over the Yaquina Bay Bridge is generated by the local logging industry.

- During the winter, the general traffic is predominantly local and in the summer the traffic includes a lot of tourists.

Based on this information, it appears that non-commercial or private vehicle traffic through the two locations on US Route 101 may be effectively targeted through resident surveys. Surveys will be sent to zip codes which are within 75 miles driving distance of these two locations. This distance will capture the commuter population as well as some occasional users of the road.

Commercial vehicle traffic driving through these two locations is likely to originate from dispatch facilities outside of the area targeted by the resident surveys. Accordingly, a second distribution is recommended to focus more specifically on trucking companies that may operate over these locations. The commercial vehicle traffic would be captured through distribution of survey forms through the Oregon Truckers Association.

In summary, two separate surveys will be mailed for this evaluation: a resident survey, and a trucker survey. Each survey will target individuals or firms located in the vicinity of the system locations or others that may operate through these two locations. In-person distribution of survey forms will be done to capture the general and commercial vehicle traffic through the Interstate 5 corridor by handing over the survey forms to the vehicles stopped at the agriculture station on the California Border approximately 13 miles north of Yreka.

Figure A-1: South Coast System Location

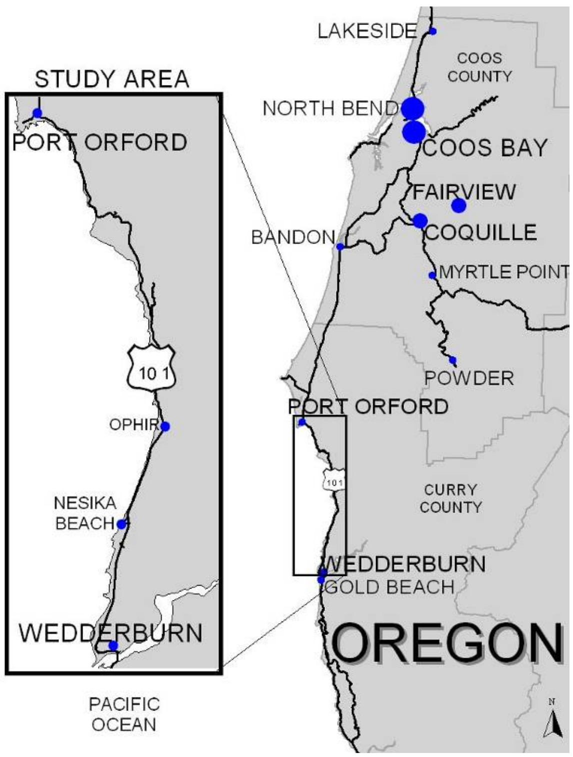


Figure A-2: Yaquina Bay System Location

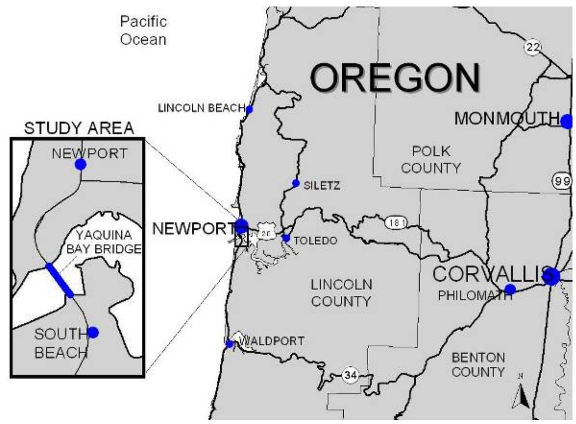
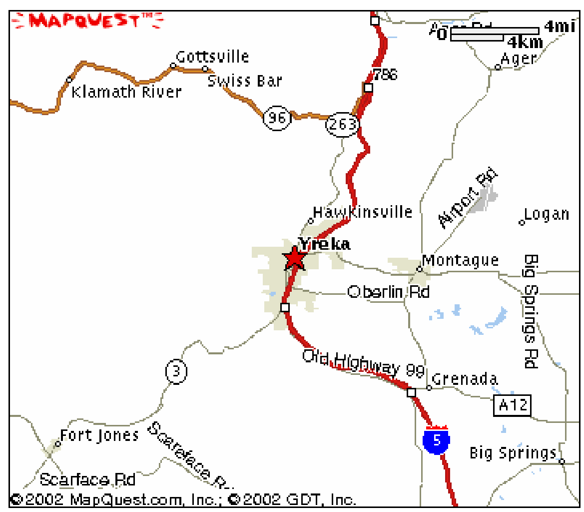


Figure A-3: Interstate 5 System Location



Sample Selection

Either random or nonrandom sampling may be used. Random sampling would mean that any driver that travels through these locations would have an equal chance of being surveyed – i.e., surveying every tenth vehicle that passes a specific point on the road. Nonrandom sampling means that some drivers have a higher chance of being surveyed than others. Examples of this might include surveying motorists at a truck stop, or surveying motorists traveling during selected hours or days.

Based on the method described, the sampling method for the surveys of motorists through the Oregon systems is nonrandom, with a bias toward residents of the Yaquina Bay area and Port Orford-Gold Beach-Brookings area and locally based trucking companies. The sampling method for the surveys of motorists through the Yreka-Weed system is random. For the resident survey, the sample would be random within the selected zip codes. Beyond this frame, caution would need to be exercised about interpretation and application of findings.

Sample Size

A minimum sample size is meaningful only when a random sampling process is employed. In those cases, the sample size is determined by the percent chance (confidence level) that the true value is within a given confidence interval (e.g. ± five percent). The minimum sample size is then determined by the following equation:

$$N = \frac{t^2 pq}{d^2}$$

where N = minimum sample size
t = constant corresponding to the desired confidence level
p = proportion of units in sample answering "yes"
q = proportion of units in sample answering "no"
d = the margin of error

For the resident survey, the desired confidence interval d is 5 percent and the confidence level is 95 percent (which leads to $t = 1.96$). To be conservative – i.e. require a larger sample size – p and q should be set at the same value, i.e. 50 percent. With these values, the minimum sample size for a random sample is estimated to be 382.

For a mailback survey without incentives, a response rate of 15 percent may be assumed. With this level of response rate, approximately 2,550 surveys for each location would need to be mailed.

Incentive

Response rate may be enhanced through an incentive to survey respondents. For this purpose, a $100 prize will be awarded to one respondent selected at random for each system. To avoid political concerns, the money to pay for this incentive will come from University Transportation Center funds administered by the Western Transportation Institute. The small population size for the trucker survey does not merit any similar cash incentive.

Language

The surveys will be distributed in an English-language format.

Question Content

The question content for both motorist surveys (general and commercial traffic) will be reviewed by the Project Evaluation Team prior to distribution. They will also be pre-tested for clarity. The survey will have questions that determine the motorists perception of the system and its' benefits. Pictures may be used to help the respondent understand what the system is.

The resident survey is intended to be completed by motorists who drive through the locations where wind warning systems are in place. The trucker survey will be addressed to trucking company dispatchers who may work with numerous drivers who travel US Route 101 through the Oregon Truckers Association, and for the system on Interstate 5 will be administered by in-person method to the drivers directly instead of reaching them through the dispatchers.

Areas of Inquiry

The following types of data will be collected in the survey.

- Trip pattern. Is the motorist a regular user of the facility? What type of vehicle do they normally use when driving over the locations of interest?
- Pre-trip information. What information does the motorist collect before traveling through these areas? What data sources do they use? These questions would help determine whether the motorist may have an expectation of travel through high winds before reaching the signs.
- Precautions. What precautions do drivers take before driving these system locations? Do they allow extra time? Do they cancel their trip?
- Perceived safety. Are motorists concerned about losing control? How concerned are travelers about high cross winds?
- Sign system. Motorists may be asked whether the sign system is clear, accurate, and useful. They may also be asked whether this type of system would be valuable at other locations. Motorists would also be asked how they react to these signs (e.g. do they change their speed? Do they avoid the trip?)
- Demographics. Zip code, age, gender and vehicle type will be asked, in order to provide more depth by which to interpret other survey responses.

Roles and Responsibilities

WTI will have overall responsibility for execution of the survey and analysis of its results. Caltrans, ODOT and other members of the Project Evaluation Team will be charged with reviewing project deliverables (including the survey instrument) in a timely fashion, and providing guidance to WTI evaluators as needed.

Task Deliverables

The motorist survey results will be analyzed for Technical Memorandum 1. Analysis will focus not only on responses to individual questions, but will also examine the relationships between different responses through cross-tabulations. This analysis may answer the following types of questions:

- Do in-state users find the system as valuable as out-of-state users?
- Do older motorists tend to feel less safe than younger motorists?
- Do truck drivers perceive a greater safety challenge at these locations than car drivers?
- Does the information on high winds reach the motorists in time? Do they perceive the information provided through the signs on high winds accurate?

Summary

South Coast System

The traffic along this corridor is predominantly commuters.

- Truckers. Mail back survey forms are to be distributed by mail through Oregon Truckers Association.
- Motorists. Mail back survey forms are to be distributed by mail to the residents within 50 miles of this corridor.

Yaquina Bay Bridge System

The traffic along this corridor is predominantly commuter type.

- Truckers. Mail back survey forms are to be distributed by mail through the Oregon Truckers Association.
- Motorists. Mail back survey forms are to be distributed by mail to the residents within 30 miles of this site.

Interstate 5 System

- Truckers. Mail back survey forms will be handed over to the truckers in the port of entry at Ashland.
- Commuters. Mail back survey forms are to be distributed by mail to the residents within 50 miles of this site.

- Long-distance travelers. Mail back survey forms are to be handed over to the people stopped at the rest area near Weed.

Schedule

The surveys will be conducted during Spring 2004.

APPENDIX B: CURRENT USE OF HIGH WIND WARNINGS

The following presents a detailed summary of the survey responses from state DOTs.

Alabama

Alabama does not have any wind detection warning systems for its highways within its ITS program, and there are not any plans to incorporate any in the future.

Arkansas

Arkansas does have locations in their highway system that experience high cross winds. At this time the Arkansas State Highway and Transportation Department does not have any planned or deployed system(s) in place to address high winds in Arkansas.

Colorado

The state of Colorado does experience high cross winds across parts of its highway system. There are not any current systems that warn motorists, maintenance or operations staff of sustained high crosswinds. At this time, State Police and/or Maintenance forces in the field request high wind warnings. Colorado DOT may collaborate with University of Wyoming on wind research.

Kansas

The state of Kansas does experience high cross winds across parts of its highway system. There are not any current or planned systems that warn motorists, maintenance or operations staff of sustained high crosswinds, but KDOT has installed wind socks which serve as the warning device in locations where crosswinds have been a particular problem (such as emerging from a road cut).

Kentucky

Kentucky does not experience any high crosswinds across its highway system.

Massachusetts

Massachusetts does not experience any high crosswinds across its highway system.

Missouri

Missouri does not experience any high crosswinds across its highway system.

Montana:

Montana has a VMS/CMS that warns motorists of sustained high cross winds between MP 330 and MP 340 on Interstate 90. This system was deployed in March 2000. The functionality of this system can be explained as follows.

Wind data collected from a RWIS are processed through a field controller, which sends a message to Traffic Management/Operations Center staff, who may remotely activate or deactivate the warning to motorists.

The identified problems for the deployment of this system are high crash frequency/severity, frequent sustained high winds and gusts of high speeds. This system met the expectations of MDT.

Nevada

The state of Nevada has a VMS/CMS that warns motorists of sustained high cross winds between CC5.5-WA7.0 on US Route 395. The functionality of this system can be explained as follows.

Wind data collected from a road weather information system (RWIS) are processed through a field controller, with motorists automatically warned when windy conditions are present.

The identified problems for the deployment of this system are high crash frequency/severity, frequent sustained high winds and gusts of high speeds. This system met the expectations of NDOT.

New Jersey

The New Jersey Department of Transportation uses no wind warning systems.

New Mexico

The state of New Mexico does experience high cross winds across parts of its highway system. There are no current or planned systems that warn motorists, maintenance or operations staff of sustained high crosswinds.

North Dakota

North Dakota does experience high crosswinds across parts of its highway system. There are no current or planned systems that warn motorists, maintenance or operations staff of sustained high crosswinds. They would like a copy of the findings of this survey.

Pennsylvania

Pennsylvania has static signs with flashing beacons that warns motorists of sustained high cross winds at various locations. They have a location that is prone to white outs caused by snow and high winds. One such white out caused a 30-car crash with 4 fatalities. The functionality of this system can be explained as follows.

Raw wind data collected from a RWIS are sent to a Traffic Management/Operations Center, which may remotely activate the motorist warning. They also have VMS/CMS to supplement the static signs with flashing beacons if needed.

PennDOT is planning to link the RWIS station with the VMSs and to upgrade the VMSs in the near future. It is expected that this will be completed by the end of 2004 provided they receive the funding. The existing wind warning systems met the expectation of PennDOT.

South Dakota

South Dakota does not experience any high crosswinds across its highway system.

Tennessee

The state of Tennessee does experience high cross winds across parts of its highway system. There are not any current or planned automated systems that warn motorists, maintenance or operations staff of sustained high crosswinds but, there are static signs at identified high wind related crash frequency/severity locations (ex: MP 104 on Interstate 65)

Utah

Utah does have locations along their highway system that experience high cross winds. Even though Utah does not have automated wind-warning systems, UDOT utilizes SSI's Scan Sentry software which can be used to set up various alarms for different environmental conditions such as wind, snow, ice formation, etc.

UDOT has RWIS stations at several wind prone areas with alarms set. TOC operators receive wind alarms and utilize one or more of more than sixty VMSs to warning motorists. Utah also has a Winter Weather Command group, made up of UDOT Motor Carrier Division, Utah Highway Patrol, Utah Trucking Association and Motor Carriers, to provide advisories to Motor Carriers with Longer Combination Vehicles, and high loads of high winds, etc. Regulations require LCVs and other oversize loads to not operate in high wind conditions.

There is also a system located at MP 322 on Interstate 15 deployed in June 2002. The functionality of this system can be described as follows.

Wind data collected from a RWIS are processed through a field controller, which sends a message to Traffic Management/Operations Center staff, who may remotely activate or deactivate the warning to motorists on VMS/CMS.

Washington

Washington State currently has four wind warning systems at the following locations.

Highway	Mile Post	Driver Notification	System Functionality	Other
SR 520	1.63 - 3.98	VMS	Wind data collected from an anemometer are processed through a field controller, which sends a message to Traffic Management/Operations Center staff, who may remotely activate or deactivate the warning to motorists.	Operator closes roadway and opens floating bridge when wind triggers alarm.
I-90	4.24 - 5.89	VMS	Wind data collected from an anemometer are processed through a field controller, which sends a message to Traffic Management/Operations Center staff, who may remotely activate or deactivate the warning to motorists.	Operator closes roadway and opens floating bridge when wind triggers alarm.
SR 104	113.93 - 14.73	VMS	Wind data collected from an anemometer are processed through a field controller, which sends a message to Traffic Management/Operations Center staff, who may remotely activate or deactivate the warning to motorists.	Operator closes roadway and opens floating bridge when wind triggers alarm.
SR 16	7.28 - 8.41	VMS	Other	TMC Operator views position of wind sock on bridge. Activates VMS if windsock is standing straight out.

The identified problem for these deployments was frequent sustained high crosswinds at these locations. These systems met the expectations of WA DOT.

<u>West Virginia</u>

The state of West Virginia does experience high cross winds across parts of its highway system. There are not too many locations that experience high cross winds. These few relatively high wind situations are mostly in the mountains or mountain passes and these locations have mostly low ADTs.

There are not any current or planned systems that warn motorists, maintenance or operations staff of sustained high crosswinds.

<u>Wisconsin</u>

The state of Wisconsin is planning a VMS / CMS that warns motorists of sustained high cross winds on Interstates 39, 90 and 94. There is an RFP out currently seeking vendors for this system. The functionality of this system can be explained as follows.

Wind data collected from a RWIS are processed through a field controller, with motorists automatically warned when windy conditions are present.

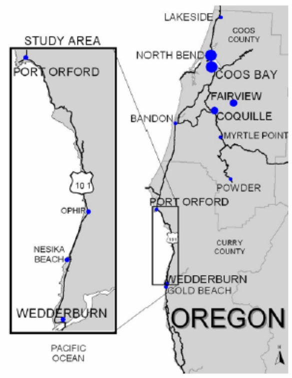
The identified problems for the deployment of this system are high crash frequency/severity and gusts of high speeds. This system met the expectations of Wisconsin DOT.

APPENDIX C: MOTORIST SURVEY INSTRUMENTS

Survey Instrument for South Coast System:

Thank you for taking the time to complete this survey! Your responses will help the Oregon Department of Transportation improve safety challenges associated with driving in high wind areas. **For your privacy, this survey is anonymous.** This project is sponsored by the U.S. Department of Transportation and is administered by the Western Transportation Institute, Montana State University - Bozeman.

1. **How often do you travel the section of Highway US 101 between Port Orford and Wedderburn (see map).** *(Check only ONE box)*
   ❒ Daily ❒ Once or twice in a week
   ❒ Once or twice in a month ❒ Once or twice in a year
   ❒ Never



2. **Did you encounter high winds when you drove this road anytime since November 2003?** *(Check only ONE box)*
   ❒ Yes ❒ No ❒ Don't recall

3. **How concerned are you about high winds when driving the section of Highway 101 between Port Orford and Wedderburn?**
   (Check only ONE box)
   ❒ Always concerned
   ❒ Concerned during this season (November to March)
   ❒ Concerned only during storms in this season (November to March)
   ❒ Not at all concerned

4. **What information sources do you use for weather information before traveling?** *(Check ALL that apply)*
   ❒ Television ❒ Newspaper
   ❒ Radio ❒ Dial 511 or 1-800-977-ODOT
   ❒ Observation of existing conditions ❒ TripCheck Website
   ❒ Other *(please specify)* ________________________ ❒ None

5. **How much do you agree with the following statements related to your driving in high winds?**
   (Circle only ONE number per line)

	Strongly Agree	Somewhat Agree	Neutral	Somewhat Disagree	Strongly Disagree
a) My vehicle may leave its lane.	5	4	3	2	1
b) My vehicle may overturn.	5	4	3	2	1
c) Other vehicles may overturn or leave their lane.	5	4	3	2	1
d) I may lose part of my cargo.	5	4	3	2	1
e) I'm more concerned about high winds with rain.	5	4	3	2	1
f) I'm more concerned about it when it is icy.	5	4	3	2	1
g) I'm not at all concerned	5	4	3	2	1

6. **When *high winds are forecasted* on this roadway, HOW LIKELY are you to?** *(Circle only ONE number per line)*

	Very Likely	Somewhat Likely	Neutral	Somewhat Unlikely	Very Unlikely
a) allow extra time for the trip?	5	4	3	2	1
b) take another route? ❒ Check if there is no alternate route	5	4	3	2	1
c) cancel trip?	5	4	3	2	1
d) decide to make the trip?	5	4	3	2	1

7. **ODOT has installed a high wind warning system for motorists on Highway US 101 between Port Orford and Wedderburn. The system includes a sign with flashing lights that is turned on during high winds as shown in the picture.**
   (Check only ONE box per question)
   a) Have you seen this sign?
      ❒ Yes ❒ No – go to Question 8
   b) Have you seen the lights on top of the sign flashing?
      ❒ Yes ❒ No – go to Question 8 ❒ Don't recall
   c) Were there high winds present when the sign was on?
      ❒ Yes ❒ No ❒ Don't recall
   d) Would you find it helpful if wind speeds were posted on the sign?
      ❒ Yes ❒ No

Survey continued on next page

8. **If the lights on the sign WERE flashing indicating high cross winds, when you are driving, HOW LIKELY would you be to…?** *(Circle only ONE number per line)*

	Very Likely	Somewhat Likely	Neutral	Somewhat Unlikely	Very Unlikely
a) drive more slowly?	5	4	3	2	1
b) pull over to the shoulder and wait?	5	4	3	2	1
c) stop at a nearby area and wait?	5	4	3	2	1
d) take an alternate route?	5	4	3	2	1
e) make no changes?	5	4	3	2	1

9. **Based on your experience, how much do you agree with the following statements.** *(Circle only ONE per line)*

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
a) This system would provide me useful information.	5	4	3	2	1
b) The system would accurately indicate when high winds are present.	5	4	3	2	1
c) I would feel safer driving this road knowing the system is in place.	5	4	3	2	1
d) This system does not sound very useful.	5	4	3	2	1

10. **Are there other locations that you travel in Oregon where this system might be beneficial? If so, please list them in the space below.**

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11. **The following information is needed to ensure that your travel needs are properly represented in this survey. It will be used for the purposes of this survey only**. *(Check ONE box per question)*

a) What is your home zip code?	Zip ______________________
b) What is your age?	❒ 15 – 24 years ❒ 25 – 44 years ❒ 45 – 64 years ❒ 65 + years
c) What is your gender?	❒ Male ❒ Female
d) What type of vehicle do you normally drive when you go on Hwy 101 between Wedderburn and Port Orford?	❒ Passenger car / pickup / Sport-utility vehicle / minivan ❒ Recreational vehicle / camper ❒ Semi Truck ❒ Bus ❒ Motorcycle ❒ Other ________________

Please provide any comments that you think would help us in this study. __________________________

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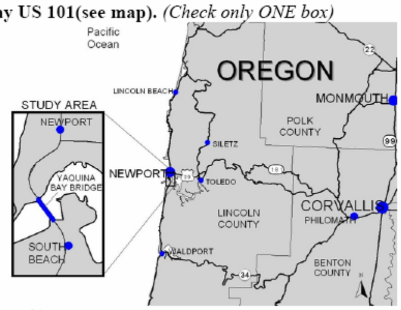
When finished, please return the completed survey in the postage paid envelope along with the yellow card to enter the drawing for $100 by **June 15, 2004**. If you are interested in receiving a summary of the survey results, please check the box on the yellow card.

THANK YOU VERY MUCH FOR YOUR PARTICIPATION!

<u>Survey Instrument for Yaquina Bay System</u>:

Thank you for taking the time to complete this survey! Your responses will help the Oregon Department of Transportation improve safety challenges associated with driving in high wind areas. **For your privacy, this survey is anonymous.** This project is sponsored by the U.S. Department of Transportation and is administered by the Western Transportation Institute, Montana State University - Bozeman.

1. **How often do you travel over Yaquina Bay Bridge on Highway US 101(see map).** *(Check only ONE box)*
   - ❒ Daily
   - ❒ Once or twice in a week
   - ❒ Once or twice in a month
   - ❒ Once or twice in a year
   - ❒ Never



2. **Did you encounter high winds when you drove over this bridge anytime since November 2003?** *(Check only ONE box)*
   ❒ Yes ❒ No ❒ Don't recall

3. **How concerned are you about high winds when driving on this bridge?** *(Check only ONE box)*
   - ❒ Always concerned
   - ❒ Concerned during this season (November to March)
   - ❒ Concerned **only during storms** in this season (November to March)
   - ❒ Not at all concerned

4. **What information sources do you use for weather information before traveling?** *(Check ALL that apply)*
   - ❒ Television
   - ❒ Newspaper
   - ❒ Radio
   - ❒ Dial 511 or 1-800-977-ODOT
   - ❒ Observation of existing conditions
   - ❒ TripCheck Website
   - ❒ Other (*please specify*) ________________________
   - ❒ None

5. **How much do you agree with the following statements related to your driving in high winds?** *(Circle only ONE number per line)*

	Strongly Agree	Somewhat Agree	Neutral	Somewhat Disagree	Strongly Disagree
a) My vehicle may leave its lane.	5	4	3	2	1
b) My vehicle may overturn.	5	4	3	2	1
c) Other vehicles may overturn or leave their lane.	5	4	3	2	1
d) I may lose part of my cargo.	5	4	3	2	1
e) I'm more concerned about high winds with rain.	5	4	3	2	1
f) I'm more concerned about it when it is icy.	5	4	3	2	1
g) I'm not at all concerned	5	4	3	2	1

6. **When *high winds are forecasted* over this bridge, HOW LIKELY are you to?** *(Circle only ONE number per line)*

	Very Likely	Somewhat Likely	Neutral	Somewhat Unlikely	Very Unlikely
a) allow extra time for the trip?	5	4	3	2	1
b) take another route? ❒ Check if there is no alternate route	5	4	3	2	1
c) cancel trip?	5	4	3	2	1
d) decide to make the trip?	5	4	3	2	1

7. **ODOT has installed a high wind warning system for motorists on Yaquina bay bridge on US Route 101. The system includes a sign with flashing lights that automatically turn on during high winds as shown in the picture.** *(Check only ONE box per question)*
   a) Have you seen this sign?
      ❒ Yes ❒ No – go to Question 8
   b) Have you seen the lights on top of the sign flashing?
      ❒ Yes ❒ No – go to Question 8 ❒ Don't recall
   c) Were there high winds present when the sign was on?
      ❒ Yes ❒ No ❒ Don't recall
   d) Would you find it helpful if wind speeds were posted on the sign?
      ❒ Yes ❒ No

Survey continued on next page

8. **If the lights on the sign WERE flashing due to high winds, when you are driving, HOW LIKELY would you be to…?** *(Circle only ONE number per line)*

	Very Likely	Somewhat Likely	Neutral	Somewhat Unlikely	Very Unlikely
a) drive more slowly?	5	4	3	2	1
b) pull over to the shoulder and wait?	5	4	3	2	1
c) stop at a nearby area and wait?	5	4	3	2	1
d) take an alternate route?	5	4	3	2	1
e) make no changes?	5	4	3	2	1

9. **Based on your experience, how much do you agree with the following statements.**
(Circle only ONE per line)

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
a) This system would provide me useful information.	5	4	3	2	1
b) The system would accurately indicate when high winds are present.	5	4	3	2	1
c) I would feel safer driving this road knowing the system is in place.	5	4	3	2	1
d) This system does not sound very useful.	5	4	3	2	1

10. **Are there other locations that you travel in Oregon where this system might be beneficial? If so, please list them in the space below.**

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11. **The following information is needed to ensure that your travel needs are properly represented in this survey. It will be used for the purposes of this survey only.** *(Check ONE box per question)*

a) What is your home zip code?	Zip ____________________
b) What is your age?	❒ 15 – 24 years ❒ 25 – 44 years ❒ 45 – 64 years ❒ 65 + years
c) What is your gender?	❒ Male ❒ Female
d) What type of vehicle do you normally drive when you go over Yaquina Bay Bridge?	❒ Passenger car / pickup / Sport-utility vehicle / minivan ❒ Recreational vehicle / camper ❒ Semi Truck ❒ Bus ❒ Motorcycle ❒ Other ______________

Please provide any comments that you think would help us in this study. ________________________

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When finished, please return the completed survey in the postage paid envelope along with the yellow card to enter the drawing for $100 by **June 15, 2004**. If you are interested in receiving a summary of the survey results, please check the box on the yellow card.

THANK YOU VERY MUCH FOR YOUR PARTICIPATION!

APPENDIX D: MOTORIST SURVEY CHI-SQUARE ANALYSIS

			South Coast System						Yaquina Bay Bridge					
Variable Grouping	**Question No.**	**Independent Variable**	**Zip Code**	**Age**	**Gender**	**Vehicle Type**	**Travel Frequ.**	**Wind Exp.**	**Zip Code**	**Age**	**Gender**	**Vehcile Type**	**Travel Freq.**	**Wind Exp.**
General	3	Wind Concerns	P	-	F	F	F	F	P	P	F	-	P	P
	4	Weather Info. Sources	F	-	P	-	F	P	P	-	P	F	P	P
High Winds Concerns	5a	Leaving Lane	P	-	F	-	P	F	P	-	P	-	P	P
	5b	Overturn	P	-	F	P	P	P	P	-	P	F	P	P
	5c	Other Vehicle	-	-	P	-	-	-	-	-	P	-	F	P
	5d	Cargo	P	-	P	-	P	P	P	-	P	P	P	P
	5e	Wind With Rain	-	-	F	-	-	-	-	-	P	P	P	P
	5f	Wind When Icy	-	-	P	-	-	-	-	-	F	-	-	-
	5g	No Concern	-	-	F	-	P	F	-	-	P	P	-	P
Response to Wind Forecast (Pre-Trip)	6a	Extra Time	-	-	F	-	P	P	P	-	P	P	P	P
	6b	Another Route	-	-	F	-	-	-	-	-	F	-	P	-
	6c	Cancel	F	-	F	P	F	P	P	-	F	F	P	P
	6d	Make the Trip	P	-	F	-	P	P	P	-	F	P	P	P
System Awareness	7a	Seen Sign	F	-	P	P	F	F	F	P	P	P	F	F
	7b	Seen Flashing	F	-	P	-	F	F	P	-	P	P	F	F
	7c	Wind Present	-	-	P	-	-	-	-	-	P	-	-	-
	7d	Wind Speeds	P	-	F	P	P	P	P	-	P	-	P	P
Response to Wind Warning System	8a	Drive Slow	-	-	-	-	-	-	-	-	-	-	-	-
	8b	Pull Over	P	-	F	-	F	P	P	-	P	P	P	P
	8c	Stop at a Rest Area	P	-	F	-	F	P	P	-	F	P	P	P
	8d	Alternate Route	-	-	P	-	-	-	-	-	F	-	F	F
	8e	No Changes	F	-	F	-	P	P	P	-	P	P	P	P
System usefulness	9a	Useful Information	-	-	-	-	-	-	-	-	P	-	-	-
	9b	Accurate Information	-	-	-	-	-	-	-	-	P	P	-	-
	9c	Feel Safer	-	-	F	-	-	-	-	-	P	P	-	P
	9d	Not Useful	-	-	P	-	-	-	-	-	P	-	P	P

Legends: P = Passed (no statistically significant dependency); F = Failed (there is a statistically significant dependency); - = Not applicable (more than 20 percent of cells had expected frequency fewer than 5)

APPENDIX E: PRE-AWWS MAINTENANCE STAFF SURVEY

ODOT and Caltrans maintenance personnel responsible for operating and maintaining the wind warning systems were asked the following questions so that the operations and maintenance could be documented.

1. What are the reasons for the deployment of the system? What is the specific problem that the system was deployed for?
2. Architecture:
    a. Who is responsible for the maintenance of specific components (Anemometer/RWIS, Controller, Static sign with flashing beacon/CMS)?
    b. What are the communication devices and medium?
3. Are archived data in terms of wind speed, direction and activation time periods available? If available who would be responsible contact point?
4. What is the wind speed thresholds used in these systems? Did the maintenance staff provide them? If so, how did you arrive at them?
5. Why and how were these locations selected for the deployment of these projects?
6. What do the maintenance staffs think that are the mileposts of influence?
7. What are the typical characteristics of the travel in these corridors? Check the proposed motorist survey method for the site.
8. Does the maintenance staff possess any records on the activation of signs before these signs were automated?
9. Have they had any liability issues with these systems?
10. Could we get a copy of the design drawings?
11. How/ why did the agency decide to deploy the particular instrument/ technology that they chose?
12. What are the pre implementation and post implementation operations procedure?

Personnel who were contacted include:

- Robert Fynn, Oregon Department of Transportation Region 2
- Jerry Gregory, Oregon Department of Transportation Region 3
- Dave Kubishta, Oregon Department of Transportation Region 2
- Galen McGill, Oregon Department of Transportation Traffic Management Section
- Phill Pitts, California Department of Transportation District 2
- Stacy Shetler, Oregon Department of Transportation Traffic Management Section
- Doug Spencer, Oregon Department of Transportation Traffic Management Section
- Ian Turnbull, California Department of Transportation District 2

1. What are the reasons for the deployment of the system? What is the specific problem that the system was deployed for?

<u>South Coast System</u>

Galen/Doug/Stacy

Safety and operational Benefits; to warn motorists of high cross winds well in advance and prevent users from being in the middle of high crosswinds.

Jerry Gregory:

The initial motivation for this system was derived from motorist staff safety concerns. While the primary reason was safety, personnel time savings by automation of turning the warning signs on, was the secondary motivation.

<u>Yaquina Bay Bridge System:</u>

Galen/Doug/Stacy

The motivation for deploying this system over the bridge is to warn the high profile vehicles before they attempt to cross the bridge so that they can take the turn around routes below the bridge to get to a rest area nearby and wait. High cross-winds typically exist for an average duration of 2- 3 hours. There are no alternates to get across the bay and the motorists would have to travel an additional 30 miles to get around the bay.

Dave Kubishta and Robert Fynn

The major reason for this deployment is the presence of a long history of wrecks on the bridge due to high crosswinds. Since this two-lane bridge is a key to the traffic across the bay, the bridge needs to be open. This system necessitates preventive measures to avoid crashes on the bridge.

<u>Interstate 5 System (Yreka)</u>:

Phill Pitt

The primary motivation for the deployment of these systems is the operational savings.

2. System Architecture:

a. Who is responsible for the maintenance of specific components (Anemometer/RWIS, Controller, Static sign with flashing beacon/CMS)?

b. What are the communication devices and medium?

<u>South Coast System</u>

Galen/Doug/Stacy

The interface (controller) is being maintained by Doug while Bill Roberts (ODOT Region 3) is maintaining the other field components (i.e. the anemometer and controller). The communication between the interface and the signs and the communication between signs and TOC are all voice modem based dial-up communication.

The anemometer is placed in Humbug Mountain. This component does not measure temperature or pressure. The Atek interface that is part of the system placed at Humbug Mountain receives wind speed and direction data and determines whether the winds are higher than 35 mph and turns on the sign at Port Orford. The sign calls up the regional TOC and reports its activation. The interface then calls up the sign at Gold Beach and activates the sign. This sign also reports to the TOC that it is activated. The same procedure is followed for deactivation of these signs. Activation and deactivation takes up to seven telephone calls. The phone line is desired to be transformed to SCR frame release network.

Jerry Gregory

Originally, the system was planned such that the signs would be turned on if there are high cross winds recorded either by the anemometer at Humbug Mountain or at the RWIS at Port Orford. The RWIS station at Port Orford is not measuring the true wind speed because it is sheltered. Now the system is planned such that the system would be turned on when the anemometer at Humbug Mountain records high cross winds.

<u>Yaquina Bay Bridge System</u>:

Galen/Doug/Stacy

There are three warning levels at this site. When wind speeds are 30-35 mph, a warning message is displayed. A caution message is issued when the wind speeds are above 60 mph and less than 85 mph. The bridge is closed for high profile traffic when the wind speeds are above 85 mph. With the current system the motorists are warned of high crosswinds when the wind speeds are above 35 mph and the maintenance staff would have to go out to close down the bridge.

Dave Kubishta and Robert Fynn:

The controller attached to the anemometer would determine whether there are hazardous conditions due to cross winds and activate the flashing beacons on the sign. The controller will also send a message to the Region 2 TOC. TOC will alert the dispatch that will send a crew to close the roads to high profile vehicles if the winds of higher speed than 80 mph.

When the system is in place, there would be two levels of warning that would be given. Level 1 (> 35 mph and < 60 mph) involves activating the signs (flashing beacons on the signs), notifying the Region 2 TOC and automatically informing the field offices, dispatch and the press by fax. Level 2 (> 60 mph) activities include all of the Level 1 activities plus sending out a crew is to close the roads for high-profile vehicles. A closure message would be posted when the signs are upgraded to a VMS.

<u>Interstate 5 System (Yreka)</u>:

No information provided.

3. Are archived data in terms of wind speed, direction and activation time periods available? If available who would be responsible contact point?

South Coast System

The wind speed and direction data are not archived. (Jerry Gregory might have recorded some of the wind speeds sporadically in a sheet of paper Ref: Sue from the kick off meeting)

Yaquina Bay Bridge System

A NTCIP- and NWS-compliant interface that works better than the Atek interface (used in the South Coast system) is being used for wind data archiving in the Yaquina Bay Bridge system. Wind speed is defined as the average of instantaneously measured speeds over two minutes, whereas gust speed is the average of instantaneously measured speeds over 10 minutes. The contact point for archived wind data is Doug Spencer.

Interstate 5 System (Yreka):

Phill Pitts:

Dino Johnson at Redding (Caltrans Dist. 2) would be contact point for any archived data. Ian mentioned that he would be able to provide the archived wind data from the RWIS server.

4. What are the wind speed thresholds used in these systems? Did the maintenance staff provide them? If so, how did you arrive at them?

South Coast System

Galen/Doug/Stacy:

The wind speed thresholds were got from the maintenance staff from their experience. The threshold is 35 mph. When the wind speed gets higher than 35 mph, the system provides motorists the advisory message by turning the flashing beacons on.

Yaquina Bay Bridge System

Galen/Doug/Stacy:

There are three warning levels at this site. When the wind speeds are 30-35 mph, a warning message is displayed. A caution message is issued when the wind speeds are above 60 mph and less than 85 mph. The bridge is closed for high profile traffic when the wind speeds are above 85 mph. With the current system the motorists are warned of high crosswinds when the wind speeds are above 35 mph and the maintenance staff would have to go out to close down the bridge.

Dave Kubishta and Robb Fynn:

When the system is in place, there would be two levels of warning that would be given. Activities for each level are described earlier.

Interstate 5 System (Yreka):

No Information provided.

5. Why and how were these locations selected for the deployment of these projects?

South Coast System

The local commuters may wait for the winds to subside while tourists may decide to proceed and find themselves in the middle of high winds. There has been a history of overturned trailers, semi trucks and single vehicle accidents caused by high crosswinds along this corridor

Yaquina Bay Bridge

Galen/Doug/Stacy

There is a good amount of truck traffic through this bridge and this bridge is the key facility to get across the bay.

Dave/Robert

The major reason for this deployment is the presence of a long history of wrecks on the bridge due to high crosswinds. Since this two-lane bridge is a key to the traffic across the bay, the bridge needs to be open. This necessitates preventive measures to avoid crashes on the bridge.

Interstate 5 System (Yreka):

Phill Pitts:

The worst wind area, influenced by Mount Shasta, is between Weed and Grenada.

6. What do the maintenance staffs think that are the mileposts of influence?

South Coast System

The milepost of influence is the corridor between the locations of static signs at Port Orford and Gold Beach.

Yaquina Bay Bridge

The milepost of influence is the length of the bridge both ways.

Interstate 5 System (Yreka)

Ian indicated that the milepost of influence is the corridor between the locations of CMS at Yreka and Weed.

7. What are the typical characteristics of the travel in these corridors? Check the proposed motorist survey method for the site?

South Coast System

Jerry Gregory

There is a significant amount of local freight up to Coos Bay and there is also good number of commuters from Brookings. (This prompted the residential survey of motorists to include the Brookings area as well). Joe Costa Trucking Company runs a lot of trucks around this corridor. There are also trucks to and from Crescent City and Smith River.

Yaquina Bay Bridge

The majority of the truck traffic is delivery truck traffic to the coast from the valley. There is also a good amount of RVs and campers driven by tourists.

Interstate 5 System (Yreka)

Phill Pitts:

The traffic here is primarily long-distance and there are high winds all around the year in this region.

8. Does the maintenance staff possess any records on the activation of signs before the signs were automated?

South Coast System

There is a local program being used by the maintenance staff that may be used to get the activation records. Bill Roberts is responsible for the maintenance of this system.

Yaquina Bay Bridge

Dave/Robb:

There are regular winds all over the year averaging at speed of 40 to 45 mph. The night crews were usually called in about 30 times a year.

Interstate 5 System (Yreka)

Phill Pitts:

The wind gets too high three to four times a year, and the roads were required to be closed at these times.

9. Have they had any liability issues with these systems?

South Coast System

These signs are just advisory, so there are no liability issues.

Yaquina Bay Bridge

These signs are just advisory in nature and the maintenance staffs go out with high patrol to close the bridge when the bridge gets closed for high profile vehicles.

Interstate 5 System (Yreka)

Phill Pitts:

No information provided.

10. Can we get a copy of the design documents?

South Coast System

Copies of the design drawings were provided.

Yaquina Bay Bridge

Copies of the design drawings were provided

Interstate 5 System (Yreka)

Phill Pitts

No design drawings; contact Ian.

11. How/ why did the agency decide to deploy the particular instrument/ technology that they chose?

South Coast System

Galen/Doug/Stacy

The Atek interface system was in place when Doug joined ODOT and Atek has been used in a flood warning system in Texas. Atek was preferred for the following reasons

1. It supports voice modem and data modem

2. It can give voice system notification over phone system during the alarm.

Yaquina Bay Bridge

Galen/Doug/Stacy

NTCIP and NWS compliant interface that works better than Atek interface for wind data archiving.

Interstate 5 System (Yreka)

The system is designed and run by the District 2 office. Phill has been out of the loop for the deployment of this system.

12. What are the pre implementation and post implementation operations procedure?

South Coast System

Galen/Doug/Stacy

This system covers 27 miles of the US Route 101 corridor from Port Orford to Gold Beach. The anemometer is placed in Humbug Mountain. The Atek interface that is part of the system placed at humbug receives the wind speed and direction data and determines whether the winds are higher than 35 mph and turns on the sign at Port orford and the sign calls up the regional TOC and reports its activation. The interface then calls up the sign at Gold Beach and activates the sign. This sign also reports to the TOC that it is activated. The same procedure is followed for deactivation of these signs. Activation and deactivation takes up to seven telephone calls. The phone line is desired to be transformed to SCR frame release network.

Yaquina Bay Bridge System

Galen/Doug/Stacy

There are three warning levels at this site. When the wind speeds are 30-35 mph, a warning message is displayed. A caution message is issued when the wind speeds are above 60 mph and less than 85 mph. The bridge is closed for high profile traffic when the wind speeds are above 85 mph.

There are no competitive alternate routes to get across the bay. There are turn around facilities near both the ends of the bridge. The road closure warning would enable the high profile vehicles to turn around and wait until the gusts die down or take another route that may be 20 to 30 additional miles.

Interstate 5 System (Yreka)

Phill Pitts:

No information provided.

APPENDIX F: POST-AWWS MAINTENANCE STAFF SURVEY

Interview responses of the maintenance staff for the South Coast and Yaquina Bay Bridge systems are presented below. Individuals contacted for this include Joel Brock (ODOT Region 3, South Coast System) and Jason Shaddix (ODOT Region 2, Yaquina Bay Bridge System).

<u>South Coast System</u>

1. Did maintenance personnel who perform road closures go back to the maintenance yard and travel back to the system location at regular intervals?

Not sure whether the roads are closed anymore. Earlier if they closed the roads, they would place a portable sign with a warning message and return to the site periodically to monitor the wind and open the roads when the winds subside.

2. How near is the nearest maintenance yard from the system location?

Two maintenance yards are used. Port Orford maintenance yard is just 3 or 4 blocks away from the sign at Port Orford. The maintenance yard close to Wedderburn is about 6 or 7 miles away.

3. Do you think that most of the drivers notice these signs?

Yes, the sign is very noticeable.

4. Do you think most of the drivers respond to these signs (by slowing down or by not traveling)?

Most of the drivers notice the signs and may slow down. Only a few drivers pull over or decide not to proceed. Automated wind warning systems at this location is an excellent idea.

5. Would broadcasting the high cross wind warnings through a HAR help the drivers significantly better?

Yes. It will be very useful especially for winds of speeds higher than 50 mph. There is an existing HAR at Bandon.

6. Do you close the roadway with the AWWS in place?

Don’t think that the roadway is closed anymore. Joel will check with the Region 3 manager and email the information.

7. Have there been any wind-related crashes at the system location after the AWWS was installed?

Not aware of any.

8. Are you aware of any instances where the system failed to warn?

Not aware of any. Joel has been watching this system closely with the RWIS software and the system seem to work very well.

System Performance:

1. In your opinion, how accurate are the wind speeds measured?

Accurate.

2. How representative are the measured wind speeds of the conditions at the location?

Representative

3. How good does the automated activation of the signs work?

Good

4. How good does the automated deactivation of the signs work?

Good

5. From your observation, how effective are the signs in getting drivers to slow down?

Good

6. Has there been a significant improvement in the safety of traveling public from the accident records or your observation?

Yes

In a scale of 1 (very ineffective) to 5 (very effective), the safety improvement from this system is about **4.5.**

Comments

It might be helpful to find a way to get drivers to pay more attention to the messages from the signs. Drivers are focused on just getting to the destination once they are on the road. So, it might also be helpful to get the information to the drivers beforehand. Providing the information through HAR also might be informative to the drivers and possibly help their safety.

Yaquina Bay Bridge System

1. Did maintenance personnel who perform road closures go back to the maintenance yard and travel back to the system location at regular intervals?

The maintenance personnel used to stay at the bridge location when the bridge was closed. They would travel to the middle of the bridge to measure the wind speeds at regular intervals since wind speeds at the ends of the bridges were not representative of the wind speeds at critical locations on the bridge.

2. How near is the nearest maintenance yard from the system location?

The bridge crew is located about 8 miles from the system location. The road closures used to use the bridge crew from this maintenance yard. There used to be about 30 closures per year before the system was in place. November used to be the month with highest number of high cross wind occurrences causing upto two closures a week.

3. Do you think most of the drivers notice these signs?

Yes.

4. Do you think most of the drivers respond to these signs (by slowing down or by not traveling)?

Yes. Have noticed the drivers pay attention to the sign and slow down. Not many drivers stop and pull over.

5. Would broadcasting the high cross wind warnings through a HAR help the drivers better?

Yes, using HAR to broadcast the warning might help if the drivers are advised well in advance of the bridge so that they could tune in to know more details on the wind event. There is an existing HAR at Newport, OR (within HAR range).

6. How often do you close the bridge at these locations with the AWWS in place?

The road closures are set to be performed when the wind speeds exceed 85 mph for a sustained period of time. But there have not been any closures in the last two years since the system was put in place. OSP officers are not needed to close down the roadway as was the case before the system was implemented.

The guess would be that there may be one road closure in about two years after the AWWS was implemented.

7. Have there been any wind-related crashes at the system location after the AWWS was installed?

Not aware of any crashes attributable to high cross winds.

8. Are you aware of any instances where the system failed to warn?

There has been one instance where an unrelated construction activity at the system location cut off the power to one side of the signs. The system has performed well in all other instances. Access to the software that pages when the activation of the signs occurs has enabled a close watch on the performance of the system and the system appears to work great.

System Performance:

1. In your opinion, how accurate are the wind speeds measured?

Very accurate

2. How representative are the measured wind speeds of the conditions at the location?

Very representative

3. How good does the automated activation of the signs work?

Very good

4. How good does the automated deactivation of the signs work?

Very Good

5. From your observation, how effective are the signs in getting the drivers to slow down?

Don't know. From general observations, it appears that drivers slow down. But, there has not been enough number of observations to conclusively say the drivers always reduce their speeds.

6. Has there been a significant improvement in the safety of traveling public from the accident records or your observation?

Don't Know. From the accident records, it is not known at this point whether there has been a significant safety benefit. From general observation, the drivers reduce their traveling speed and there could be safety benefits from the reduced (safer) traveling speeds for high wind conditions. The perceived safety of traveling through this site can also be considered improved.

Comments

<u>Possible Improvements</u>. Installing variable message signs (VMS) will help the drivers as they can get more information on the wind event (e.g. wind speed). Adding an automation of the HAR messaging and signing at appropriate locations may also help the drivers. But, the benefit to cost ratio of adding a HAR should be further investigated as road closures are rare and HAR messages might be useful only when road closures occur.

<u>Other Comments</u>. The current location of the anemometer on the bridge requires lane closures when maintenance activities need to performed on the anemometer. It also requires a 50-ft. truck that the maintenance yard has to borrow from other sources. The average cost of performing maintenance on the anemometer about once in two years is about $2,000. This regular maintenance takes about four people staying overnight at Newport and the personnel are paid overtime as the lane closure can be done only at nights. There is a proposal in consideration to move the anemometers closer to the ends of the bridges so that the maintenance can be performed from the ground and also lane closures can be avoided.

APPENDIX G: ACTIVATION RECORDS

Activation Records for Warning Signs at Port Orford and Gold Beach

LOCATION	TIMES		DURATION
(Hwy 101)	DATE / HOUR ON	DATE / HOUR OFF	
MP 300	2/17/02 23:18	2/18/02 7:24	8:06:00
MP 327	2/17/02 23:20	2/18/02 8:30	9:10:00
MP 300	2/23/02 23:18	2/24/02 7:24	8:06:00
MP 327	2/23/02 23:20	2/24/02 8:30	9:10:00
MP 300	2/25/02 7:00	2/26/02 10:05	27:05:00
MP 327	2/25/02 7:00	2/26/02 10:05	27:05:00
MP 300	3/1/02 0:15	3/1/02 8:28	8:13:00
MP 327	3/1/02 0:15	3/1/02 8:28	8:13:00
MP 300	4/19/02 12:09	4/20/02 8:30	20:21:00
MP 327	4/19/02 12:57	4/20/02 8:13	19:16:00
		Avg. Duration	14:47:48

Activation Records for Warning Signs at Yaquina Bay Bridge

Event #	Date / Hr On	Date / Hr Off	Duration
1	12/13/04 15:51	12/13/04 17:01	1:10
2	12/25/04 7:43	12/25/04 16:23	8:40
3	2/28/05 11:31	2/28/05 12:41	1:10
4	3/16/05 11:13	3/16/05 15:37	4:24
5	3/19/05 14:15	3/20/05 7:05	16:50
6	3/20/05 7:55	3/20/05 8:25	0:30
7	3/20/05 17:15	3/20/05 20:05	2:50
8	3/20/05 20:55	3/20/05 21:05	0:10
9	3/26/05 3:46	3/26/05 5:42	1:56
10	3/26/05 9:24	3/26/05 9:34	0:10
11	3/26/05 9:44	3/26/05 10:04	0:20
12	3/26/05 10:34	3/26/05 11:44	1:10
13	3/26/05 11:54	3/26/05 13:19	1:25
14	3/26/05 13:34	3/26/05 19:54	6:20
10-14			10:30
15	3/26/05 21:55	3/26/05 22:25	0:30
16	3/26/05 22:35	3/26/05 23:25	0:50
17	3/26/05 23:35	3/26/05 23:55	0:20
18	3/27/05 0:05	3/27/05 3:05	3:00
15-18			5:10
19	3/27/05 3:25	3/27/05 9:59	6:34
20	3/28/05 8:41	3/28/05 11:12	2:31
21	3/28/05 23:02	3/29/05 1:10	2:08
22	3/29/05 4:24	3/29/05 4:52	0:28
23	4/12/05 7:19	4/12/05 7:29	0:10
24	4/12/05 9:40	4/12/05 10:20	0:40
25	4/12/05 17:30	4/12/05 17:50	0:20
26	4/16/05 1:23	4/16/05 3:13	1:50
27	4/16/05 5:24	4/16/05 5:34	0:10
28	4/16/05 6:54	4/16/05 7:04	0:10
29	4/23/05 3:22	4/23/05 4:12	0:50
30	5/18/05 11:22	5/18/05 12:42	1:20
31	5/18/05 14:42	5/18/05 15:02	0:20
32	5/18/05 15:22	5/18/05 15:52	0:30
31-32			1:10
33	5/19/05 2:13	5/19/05 3:33	1:20
34	5/21/05 16:25	5/21/05 16:35	0:10
35	5/21/05 18:15	5/21/05 19:35	1:20
36	6/5/05 10:36	6/5/05 10:46	0:10
		Average	2:40

APPENDIX H: STANDARD OPERATING GUIDELINES

<u>South Coast System</u>:

Oregon Department of Transportation

	NUMBER: 50.7A
	SUPERSEDES: May 19, 2005
	EFFECTIVE DATE: June 21, 2005
	PAGES: 1
Transportation Operations Center Standard Operating Guideline	**REVIEW AND VALIDATION DATE:** April 11, 2005
	REFERENCES: None
SUBJECT: Port Orford and Hunter Creek Weather Warning System Data Notification	**APPROVAL SIGNATURE:**

PURPOSE: The Weather Warning System (WWS) for high winds located on US101 near Port Orford automatically detects excessive wind speeds in the area. When high wind conditions are detected, the system automatically activates flashing beacons to warn motorists of a high wind situation, notifies TOCs by way of HTCRS, and notifies various ODOT individuals by way of pages.

<u>RESPONSE GUIDELINE</u>

1. The flashing beacons at Port Orford and Wedderburn will automatically turn on when the average wind speed reaches 35 mph. They will automatically turn off when Deactivation Condition Level 1 is met. Crews will not be paged when the signs turn on and off.

2. An unreviewed incident of severity 0 will be created for insertion into HTCRS when wind speeds detected are between 35 mph and 80 mph. These incidents will require dispatcher review and verification.

3. An unreviewed incident of severity 2 will be created for insertion into HTCRS when speeds detected are greater than 80 mph. These incidents will require dispatcher review and verification.

4. Wind data can be accessed in SCANWeb (http://s-salemrev-11/scanweb/swframe.asp).

<u>UPDATES AND CHANGES</u>

- Contact ITS Operations Coordinator 503-986-6568 with recommended updates and changes.

Yaquina Bay Bridge System:

Oregon Department of Transportation

NUMBER:	SUPERSEDES:
50.7B	Initial Publication
EFFECTIVE DATE:	PAGES:
March 18, 2005	6

Transportation Operations Center
Standard Operating Guideline

REVIEW AND VALIDATION DATE:
April 1, 2005

REFERENCES:
Activation and Deactivation Fax Sheets

SUBJECT:
Yaquina Bay Weather Warning System Data Notification

APPROVAL SIGNATURE:

PURPOSE: The Weather Warning System (WWS) for high winds located at Yaquina Bay automatically detects excessive wind speeds in the area. When high wind conditions are detected, the system automatically activates flashing beacons to warn motorists of a high wind situation, notifies TOCs by way of HTCRS, and notifies various ODOT individuals by way of pages.

BACKGROUND INFORMATION

1. The WWS is designed to automatically alert the appropriate constituents via page or email based on the various condition levels:

    a. Condition Level 0 – Average wind speed reaches 45 mph.
    b. Condition Level 1 – Average wind speed reaches 60 mph.
    c. Condition Level 2 – Average wind speed reaches 80 mph.
    d. Deactivation Condition Level 1 – Average wind speed drops to 35 mph.

2. The flashing beacons will automatically turn on when the average wind speed reaches 35 mph. They will automatically turn off when the wind speed drops below 25 mph.

3. An unreviewed incident of severity 0 will created for insertion into HTCRS when wind speeds detected are between 35 mph and 80 mph. These incidents will require dispatcher review.

4. An unreviewed incident of severity 2 will be created for insertion into HTCRS when speeds detected are greater than 80 mph. These incidents will require dispatcher review.

5. Data should also appear in SCAN (http://s-salemrev-11/scanweb/swframe.asp)

RESPONSE GUIDELINES

1. HTCRS will automatically generate an incident of severity 0 requiring dispatcher review.

- **Condition Level 0:**
  1. HTCRS will automatically page the ODOT appropriate staff via the **Yaquina Bay Page List** and the **Yaquina Bay Email List** in Outlook. To modify the list (add, remove, or update), please contact the ITS Operations Coordinator.
  2. HTCRS will automatically generate an incident of severity 0 requiring dispatcher review.

- **Condition Level 1:**
  1. HTCRS will automatically page the ODOT appropriate staff via the **Yaquina Bay Page List** and the **Yaquina Bay Email List** in Outlook. To modify the list (add, remove, or update), please contact the ITS Operations Coordinator.
  2. HTCRS will automatically generate an incident of severity requiring dispatcher review.
  3. Dispatchers should verify wind conditions using the OSU Marine Science Center weather Web site (http://weather.hmsc.oregonstate.edu/) or with crew on schedule before accepting the incident in HTCRS. Newport Bridge Crew will advise if bridge will be closed to high profile traffic and set signs to detour traffic. Dispatchers should modify the incident according to updates provided by the Bridge Crew.
  4. Dispatchers will fax a Level 1 notice to the following constituents:

FAX / CALL LIST FOR CONDITION LEVEL 1 – PENDING CLOSURE LIST

Contact	Phone	Fax	Comments
Lincom/ Newport Police	**(541) 265-4231**	**(541) 265-3766**	
OSP	**(541) 265-5353**	**(503) 585-6635**	
Lincoln County School Dist.	**(541) 265-9211**	**(541) 336-5400**	**8am to 5pm Mon. – Fri.**
Debbie Miller	**(541) 265-9543**	**NA**	**After hours**
Rich Belloni	**(541) 265-2486**	**NA**	**After hours**
KYTE	**(541) 265-2266**	**(541) 265-6397**	
KNPT	**(541) 265-2266**	**(541) 265-9576**	
KSHL	**(541) 265-6477**	**(541) 265-6478**	
KPPT	**(541) 265-5000**		
KSND	**(541) 574-1005**	**(541) 574-0791**	
KORC	**(541) 563-5100**	**(541) 563-5116**	

1. will be closed to high profile traffic and set signs to detour traffic. Dispatchers should modify the incident according to updates provided by the Bridge Crew.
2. Dispatchers will fax a Level 2 notice to the following constituents:

FAX / CALL LIST FOR CONDITION LEVEL 2 – CLOSURE LIST

Contact	Phone	Fax	Comments
Lincom/ Newport Police	**(541) 265-4231**	**(541) 265-3766**	
OSP	**(541) 265-5353**	**(503) 585-6635**	
Lincoln County School Dist.	**(541) 265-9211**	**(541) 336-5400**	**8am to 5pm Mon. – Fri.**
Debbie Miller	**(541) 265-9543**	**NA**	**After hours**
Rich Belloni	**(541) 265-2486**	**NA**	**After hours**
KYTE	**(541) 265-2266**	**(541) 265-6397**	
KNPT	**(541) 265-2266**	**(541) 265-9576**	
KSHL	**(541) 265-6477**	**(541) 265-6478**	
KPPT	**(541) 265-5000**		
KSND	**(541) 574-1005**	**(541) 574-0791**	
KORC	**(541) 563-5100**	**(541) 563-5116**	
Oregon Trucking Association	**(888) 293-0005**	**(503) 513-0008**	

- **Deactivation Condition:**

1. HTCRS will automatically page the ODOT appropriate staff via the **Yaquina Bay Page List** and the **Yaquina Bay Email List** in Outlook. To modify the list (add, remove, or update), please contact the ITS Operations Coordinator.
2. HTCRS will close the incident.
3. Dispatchers will fax a deactivation notice to the following constituents.

FAX / CALL LIST FOR DEACTIVATION LEVEL – HIGHWAY OPENED LIST

Contact	Phone	Fax	Comments
Lincom/ Newport Police	**(541) 265-4231**	**(541) 265-3766**	
OSP	**(541) 265-5353**	**(503) 585-6635**	
Lincoln County School Dist.	**(541) 265-9211**	**(541) 336-5400**	**8am to 5pm Mon. – Fri.**
Debbie Miller	**(541) 265-9543**	**NA**	**After hours**
Rich Belloni	**(541) 265-2486**	**NA**	**After hours**
KYTE	**(541) 265-2266**	**(541) 265-6397**	
KNPT	**(541) 265-2266**	**(541) 265-9576**	
KSHL	**(541) 265-6477**	**(541) 265-6478**	
KPPT	**(541) 265-5000**		
KSND	**(541) 574-1005**	**(541) 574-0791**	
KORC	**(541) 563-5100**	**(541) 563-5116**	
Oregon Trucking Association	**(888) 293-0005**	**(503) 513-0008**	

UPDATES AND CHANGES

- Contact ITS Operations Coordinator 503-986-6568 with recommended updates and changes.

REFERENCES

Level 1 Fax Sheet, Level 2 Fax Sheet, and Deactivation Fax Sheet can be found on the subsequent pages.

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