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Road Weather Information Systems: Enabling Proactive Maintenance Practices in Washington State

by

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16. ABSTRACT

Washington State Department of Transportation's (WSDOT) rWeather program has significantly integrated and expanded the capabilities of road weather information systems (RWIS) in the state, enabling proactive winter maintenance practices and better-informed winter travel decisions. The report reviews the potential benefits of a comprehensive, integrated RWIS, including cost-efficient snow and ice control strategies and improved safety and mobility. Use of, and attitudes toward, RWIS by WSDOT maintenance personnel are examined, and barriers to the expanded use of RWIS technologies are identified. Public response to the rWeather traveler information website is evaluated. Recommendations are presented for more fully utilizing RWIS capabilities.

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EXECUTIVE SUMMARY

Like many other states, Canadian provinces, and Scandinavian and European countries, the Washington State Department of Transportation (WSDOT) has invested in advanced technologies designed to monitor, report and forecast road related weather conditions. Collectively, these technologies are referred to as Road Weather Information Systems (RWIS). In Washington, deployed RWIS components include roadside sensor stations, a statewide communication network, data access tools for maintenance personnel, tailored weather forecasting services, advanced weather modeling, pavement temperature modeling and prediction, and an Internet website for maintenance decision making and traveler information. Implementation of these RWIS components serves primarily to help WSDOT maintenance personnel make timely and efficient winter maintenance decisions. It enables the use of cost-effective, proactive snow and ice control practices that improve safety and the level of service provided to users of the state highway system. This same road condition and weather information is disseminated to the public as a way of helping travelers make informed decisions for safe and efficient travel.

In 1998 WSDOT began a program to greatly expand and improve weather data available to both WSDOT maintenance personnel and the traveling public. The program, called rWeather, has resulted in a statewide network of weather stations that includes not only those sensor stations owned by WSDOT but also almost 400 other stations owned by nine other federal, state, and local agencies.

The objective of this research is to document the reported benefits of RWIS, assess the extent to which these benefits are being realized in Washington, and identify strategies and operational changes necessary to take full advantage of RWIS technology. The overall intent is to provide information to support future RWIS-related investment decision-making.

Winter Maintenance in Washington State

Snow and ice control practices are designed to keep roadways passable and as safe as possible during winter weather conditions. Of all the injury and fatality accidents in Washington from 1991 through 1996, nearly 8 percent (9000) occurred during conditions of snow and ice. Just in the past two years (1999 and 2000), 3,675 people have been injured and 64 people have died in accidents during conditions of snow and ice[1].

The costs of winter road maintenance are substantial. Over the last four winters annual costs for snow and ice control have climbed from $21 million to just over $26 million. Seventy percent of all snow and ice control expenses are borne by three WSDOT districts: the South Central Region, the North Central Region and the Eastern Region. Labor expenses generally account for 40 percent of the total costs, equipment for about 30 percent, and materials for roughly 25 percent[2].

The potential benefits of RWIS are substantial. Investments in RWIS can provide travelers with better information for safe and efficient travel, provide information useful for efficient scheduling of maintenance personnel, enable maintenance personnel to cost-effectively provide a higher level of service, and provide higher quality observational data for improved weather forecasting. However, nearly all of these benefits result only when winter maintenance practices are significantly changed to take advantage of RWIS capabilities.

Without detailed, tailored, and targeted weather forecasts, winter maintenance decisions must be based on current weather conditions. Traditionally, winter maintenance managers have reacted to current conditions. In contrast, the information available from a fully deployed RWIS makes it possible to adopt new, proactive ways of doing business that can more efficiently and cost-effectively provide safer conditions for the traveling public. These RWIS-enabled practices include the following:

[1] Data provided by the Transportation Data Office.
[2] Data provided Highway Maintenance, Field Operations Support Service Center.

- Anti-icing – the practice of applying chemicals to the road surface before a weather event to prevent bonding of snow and ice to the road rather than having to work harder to break the bond after it has already formed.
- Reduced use of routine patrols – a result of having sensor stations and cameras reporting conditions from remote locations.
- Cost-effective allocation of resources – putting the right amount of people, equipment and materials where they are needed, when they are needed, including eliminating routine night and weekend shift work.
- Provide travelers better information – travelers with better information about weather conditions can be better prepared for, or avoid altogether, poor driving conditions.
- Cost-effective summer maintenance scheduling – pavement temperature forecasts can be used to schedule paving operations when conditions will be conducive.
- Share weather data – RWIS sensor stations can provide weather observations at key locations for weather forecast modeling.

In Washington, the North Central Region reports benefits of anti-icing operations enabled to some extent by RWIS, including improved employee satisfaction and increased productivity as a result of eliminating most regular night shift assignments, as well as the ability to provide a higher level of service for the same cost.

The literature offers no comprehensive benefit-cost studies of implemented RWIS programs in the North America. Furthermore, no large-scale RWIS systems have yet to be fully incorporated into winter maintenance operations. However, several benefit/cost studies have been based on **expected** benefits in comparison to projected or actual costs.

WSDOT's North Central Region has led the state in terms of adopting anti-icing and using tailored weather forecasts. The region's maintenance staff have reported several benefits, including less sand used, less sand cleanup, less guardrail damage,

elimination of weekend shifts, call-out and overtime savings, a lower accident rate, fewer tort claims, better level of service, fewer equipment hours, positive public feedback, and "happier environmentalists".

RWIS-supported changes in snow and ice control practices are still too new to have achieved consistent region-wide application and to demonstrate clear trends. A review of maintenance expenditures and accident records reveals no clear evidence that these benefits are substantial enough to be detected in cost figures for snow and ice control. The number of accidents, in particular, is highly variable, with no clear trends visible in the short term. Region management has stressed that the most significant result to date has been an increase in the level of service offered to the public without an increase in cost.

WSDOT Maintenance Personnel Survey

WSDOT maintenance personnel were surveyed during May and June of 2001 about their use of, and attitudes toward, various sources of road weather information. Questionnaires were mailed to all 24 maintenance area superintendents with instructions to complete the questionnaire themselves and distribute copies of it to supervisors and lead technicians within their area. A total of 129 questionnaires were returned (a 51 percent return rate), of which 44 percent were superintendents or supervisors and 56 percent were lead technicians. The most significant results are listed below:

- Snow and Ice Control Practices: Patrols were used extensively by nearly half of the respondents; about one third reported using anti-icing or plowing and sanding extensively, and less than 15 percent reported using de-icing extensively.
- Weather Information Sources: Overall, the most used weather information resources were patrols, local broadcast TV, local broadcast radio and the World Wide Web. Twice as many supervisory staff as lead techs used

SCAN Web, and more than twice as many supervisory staff as lead techs used rWeather. Private sector weather forecasting services and rWeather were used more in the North Central Region, where anti-icing is heavily used, than in any other region.

- Satisfaction with Available Weather Information: Just over 65 percent of respondents indicated that they were very or generally satisfied with the weather information they had available for winter maintenance decisions. Only 2 percent indicated that they were not at all satisfied. Respondents in the Eastern and North Central regions indicated a slightly lower level of satisfaction with the weather information they had available than those in the South Central, Olympic and Northwest regions.
- Savings from Detailed Weather Information: Sixty-five percent of supervisory staff had experienced more efficient allocation of labor as the result of using detailed weather information. Between 40 and 50 percent indicated that they had experienced labor hour and equipment hour reductions and lower material costs.
- Improvements to Weather Information: Improved reliability and more detailed forecasts targeted to specific areas topped the list of valuable improvements.
- Potential to Reduce Routine Patrols and Increase Anti-icing: Reducing routine road patrols and increasing the use of anti-icing strategies would be two primary ways that RWIS could generate safety and cost effectiveness benefits for WSDOT. More respondents projected an increase in the use of anti-icing as a result of improved weather information than those who projected a reduction in routine road patrols.

- Internet Access: One hundred percent of the supervisory staff responding to the survey reported having Internet access at work. In contrast, less than 70 percent of the lead personnel reported having Internet access at work.
- Adequacy of Training in Interpreting Weather Information: Although 74 percent of the respondents who had received training reported that the training was adequate for making snow and ice control decisions, more than half (54 percent) of the respondents indicated that they had not received any training at all in interpreting weather information.
- Satisfaction with RWIS Stations: Forty-one respondents indicated that they had an RWIS sensor station in their maintenance area, and the majority of these indicated that they were only somewhat satisfied with its accuracy, location, and reliability. Among those with RWIS stations, satisfaction with RWIS training varied considerably by region. Half or more of the respondents in the Eastern, Northwest and South Central regions indicated that they were not at all satisfied with the availability of RWIS training. Of those respondents with an RWIS station in their area, more than half indicated that they did not use SCAN Web.
- Additional RWIS Stations: Eighty-four percent indicated that additional RWIS stations in their maintenance area would be useful in making snow and ice control decisions.
- RWeather: Seventy-nine percent of the respondents indicated that they were aware of the rWeather website, and of those, 78 percent had used it. National Weather Service warnings, satellite and radar images, and the statewide weather map were cited as the most valuable features of rWeather. Nine of the twelve features identified were rated as very useful or somewhat useful by over half of the respondents.

- Additional Road Weather Information Investments: Respondents were asked to indicate the RWIS-related activities in which they would like to see WSDOT invest additional resources. Nearly 70 percent indicated that they would like to see more investment in training related to interpreting weather data. Additional RWIS stations and training related to anti-icing strategies were cited by just about half of the respondents. Additional resources for RWIS station maintenance and operations and additional investment in providing weather and road condition information to the public followed at more than 40 percent.

RWeather Customer Survey

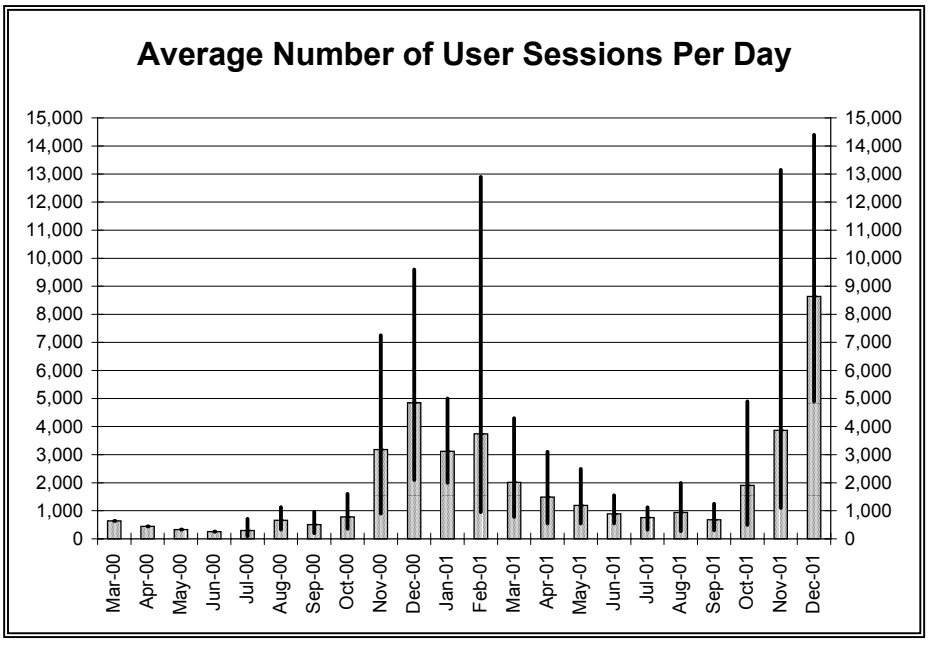
Visitors to the rWeather website were invited to respond to a short on-line survey from March 6, 2001, to April 9, 2001. During that time 140 members of the public filled out the survey. The objectives of this survey were to better understand who used the site, what kinds of trips they were planning with information they derived from the site, the features of the site they used and how useful they found these features to be for their trip planning, and suggestions they might have for enhancing the overall value of the site.

The survey respondents were overwhelmingly positive in their assessment of the value of the rWeather website in helping them prepare for their travel and learn about weather and road conditions. Use of this site differs from that of many other traveler information sites in that users are predominantly focused on longer trips. More than twice as many users said they were most frequently planning recreational, business, and other personal trips of over 100 miles than those using the website to plan shorter trips.

Virtually all of the site's informational features were used by most visitors, and their ratings of the usefulness of these features were high for all the main features, including weather conditions, mountain pass conditions, traffic cameras, road temperatures, and state-wide maps. About half the respondents offered specific

suggestions that tended to cluster around several common topics, including a desire for more camera images, more current information, broader and more consistent geographic coverage, and some site design modifications. The great majority of users who responded to the survey said they considered the site well organized and generally easy to use, with information that is easy to find. Some concerns were reported regarding site usability, and evidence suggested that first-time users have more difficulties than experienced users. Overall, however, the response to this website was very positive. Comments such as, "The website is terrific," and "One of the best sites that I have seen," capture the opinion of many of the survey respondents.

Use of the rWeather website is growing. Overall use of the website increased 86 percent from 2000 to 2001(March through December), nearly doubling the number of rWeather users. The winter months experience the highest levels of use, as well as the most extremes of usage on a day-to-day basis, as shown on the figure below. (For example, February 2001 included a snowy Friday before a holiday weekend.)



Average Daily rWeather User Sessions

Findings and Recommendations

Major strides have been made recently in WSDOT's implementation of RWIS as a result of the rWeather program. The most significant of these are equipment compatibility; development of a statewide RWIS network, including an extensive set of non-WSDOT weather sensors; access to statewide comprehensive weather information; weather training; and a successful public information website.

WSDOT maintenance personnel, however, are not taking full advantage of the state's RWIS investment. At the same time, it is clear that enthusiasm for implementing advanced snow and ice control practices is growing and maintenance personnel have expressed extensive support for additional RWIS stations and weather interpretation training. The barriers to the full use of RWIS capabilities and the recommendations to address these barriers are summarized below.

Barriers

- Lack of experience with RWIS technology and proactive winter maintenance practices.
- Lack of confidence in weather and pavement forecasts and RWIS sensor information.
- Lack of access to the Internet, a primary source of weather information including the rWeather website.
- Lack of training in interpreting weather information and the use of advanced snow and ice control practices.
- Resistance to making the changes in current practices that will result in significant cost savings.
- Liability concerns related to both using anti-icing strategies and not using anti-icing strategies.

- RWIS equipment reliability and long-term maintenance concerns, and limitations of the rWeather website for winter maintenance decision-making.
- Limitations of existing technology, including chemical detection in road sensors and current limits of weather forecasting technologies.

Recommendations

1. Continue to share information about experiences with RWIS and advanced winter maintenance practices as a way to reduce barriers to expanded use.
2. Document and review snow and ice control methods and results throughout the winter season.
3. Document the reliability of rWeather pavement temperature forecasts and share the results with winter maintenance personnel.
4. Require weather forecast service to meet defined performance criteria.
5. Provide computers and Internet access in all maintenance sheds and ensure that computers with Internet access are available to all personnel tasked with making winter maintenance decisions.
6. Provide training, particularly in the interpretation of weather information and the application of anti-icing strategies. Make an effort to focus the right training on the right people.
7. Train maintenance personnel in the potential pitfalls of the multitude of Internet sources of weather information and the best way to take advantage of them.
8. Provide strong management support for the need to adopt advanced winter maintenance practices and demonstrate a commitment to necessary training.

9. Continue efforts to educate the public about the potential safety, cost, and environmental benefits of using anti-icing chemicals.
10. Develop a well-documented plan for statewide uniform implementation of advanced winter maintenance practices to address liability concerns.
11. Make a full review of the accuracy and reliability of all RWIS sensor station equipment.
12. Ensure funding for ongoing maintenance of RWIS sensor stations.
13. Consider ongoing funding of centralized RWIS technical support.
14. Focus additional RWIS resources on areas where the potential to change snow and ice control practices exists and where additional sensor capability will contribute to improved weather forecasting.

Many of these recommendations are already being addressed through continued investments in RWIS sensor stations, Internet access, and additional weather-related training. In addition, current plans call for hiring a meteorologist to address the need for analysis of statewide forecast reliability and equipment performance.

RWIS enables cost effective, proactive winter maintenance practices that improve the level of service provided and lead to increased safety and mobility for the traveling public. Although proactive maintenance practices such as anti-icing can be implemented without a comprehensive RWIS, such implementations are very costly because use of labor, equipment, and materials is often beyond what is necessary. Expanding the use of RWIS and advanced winter maintenance practices will require management commitment and continued investment in equipment reliability, demonstration of forecast credibility, targeted training, and implementation planning.

SECTION 1: INTRODUCTION

Like many other states, Canadian provinces, and Scandinavian and European countries, the Washington State Department of Transportation (WSDOT) has invested in advanced technologies designed to monitor, report, and forecast road related weather conditions. Collectively, these technologies are referred to as Road Weather Information Systems (RWIS). In Washington, deployed RWIS components include roadside sensor stations, a statewide communication network, data access tools for maintenance personnel, tailored weather forecasting services, advanced weather modeling, pavement temperature modeling and prediction, and an Internet website for maintenance decision making and traveler information. Implementation of these RWIS components serves primarily to help WSDOT maintenance personnel make timely and efficient winter maintenance decisions. It enables the use of cost-effective proactive snow and ice control practices that improve safety and the level of service provided to users of the state highway system. This same road condition and weather information is disseminated to the public as a way of helping travelers make informed decisions for safe and efficient travel.

Roadside RWIS station implementation in Washington began in the early 1980s. These sensor stations consist of equipment that constantly measures and reports atmospheric and road conditions such as temperature, wind speed, and humidity. WSDOT currently has just over 50 RWIS stations spread throughout the state. (The number of RWIS stations is expected to grow to more than 60 by next year.) In 1998 WSDOT began a program to greatly expand and improve weather data available to both WSDOT maintenance personnel and the traveling public. The program, called rWeather, has resulted in a statewide network of weather stations that includes not only those sensor stations owned by WSDOT but also almost 400 other stations owned by nine other federal, state, and local agencies.

With so much progress in the implementation of RWIS infrastructure it is timely to assess the extent to which the expected benefits of RWIS are being realized in Washington State. As with many other new technologies, the benefits of RWIS are limited if business practices don't change to take advantage of the opportunities provided by the technology.

BACKGROUND

RWIS research and testing began in the United States as part of the Strategic Highway Research Program (SHRP). During the winter of 1990/1991, seven states participated in a test of RWIS that was documented in "Road Weather Information Systems Volume 1: Research Report" (Boselly 1993). The study concluded that "tailored and detailed forecasts based on a combination of RWIS sensor and thermal analysis can result in a return on investment of close to five hundred percent, and can significantly improve service levels and greatly decrease the frequency of decision errors," with the following caveats:

- The best return on investment results when highway maintenance managers use tailored and detailed weather and pavement forecasts for snow and ice control decisions.
- Sensor reliability and accurate output requires a preventive or routine maintenance program and at least annual calibration of sensors.
- RWIS information must be made available to the lowest level of decision-makers to be most effective.
- Effective communication is necessary between forecasters and maintenance managers to ensure that forecasters understand the needs of managers and that managers understand the weather information.
- Philosophical and psychological barriers exist to integrating RWIS technologies into snow and ice control operations. These include distrust

of weather forecasts, fear of change, and the perception that the technology is difficult to implement. These barriers can be overcome through training.

Part of the intent of this research effort is to review and update these findings.

PURPOSE

The objective of this research is to document the reported benefits of RWIS, assess the extent to which these benefits are being realized in Washington, and identify strategies and operational changes necessary to take full advantage of RWIS technology. The overall intent is to provide information to support future RWIS-related investment decision-making.

The primary elements of this research effort are a literature review of benefits and previous benefit/cost ratio studies, a survey of WSDOT maintenance personnel regarding winter maintenance practices and attitudes, and an on-line survey of travelers who use the rWeather website to determine customer satisfaction with road weather information.

The next section provides background information about winter maintenance challenges in Washington and an overview of RWIS technologies and their implementation in the state. Section 3 describes the expected and experienced benefits of RWIS, and Sections 4 and 5 discuss the two survey activities and their results. Findings, recommendations, and conclusions are presented in Sections 6 and 7.

SECTION 2: RWIS IN WASHINGTON STATE

WINTER ROAD MAINTENANCE IN WASHINGTON

Winter weather, and the snow and ice control strategies necessary to deal with it, varies considerably throughout the state. The state can be divided into three areas: the Mountains which receive heavy snowfall and for which the primary winter maintenance activity is snow removal; the Coastal Lowlands, which experience occasional frost and rare snow events and require anti-icing and sanding for icy highways; and the Inland Plateau, which experiences numerous frost events and moderate snowfall for which the primary activity is management of icy roads using anti-icing and sanding (Baroga 2000).

Snow and ice control practices are designed to keep roadways passable and as safe as possible during winter weather conditions. Of all the injury and fatality accidents in Washington from 1991 through 1996, nearly 8 percent (9000) occurred during conditions of snow and ice. Just in the past two years (1999 and 2000), 3,675 people have been injured and 64 people have died in accidents during conditions of snow and ice[3].

The costs of winter road maintenance are substantial. Over the last four winters annual costs for snow and ice control have climbed from $21 million to just over $26 million. Seventy percent of all snow and ice control expenses are borne by three of WSDOT's districts: the South Central Region, the North Central Region, and the Eastern Region. See Figure 2-1. Labor expenses generally account for 40 percent of the total costs, equipment for about 30 percent, and materials for roughly 25 percent[4].

[3] Data provided by the Transportation Data Office.
[4] Data provided Highway Maintenance, Field Operations Support Service Center.

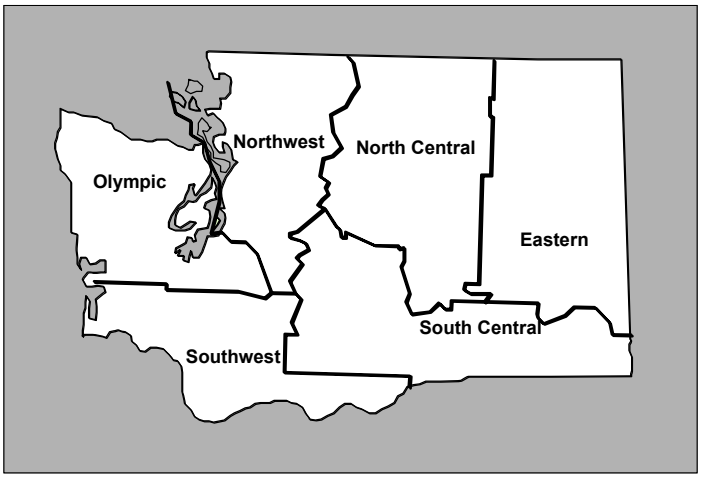


Figure 2-1: Washington State Regions

RWIS COMPONENTS

The term RWIS refers broadly to a set of road-related weather observation, forecasting, and reporting technologies. Most generally, RWIS refers to the roadside sensor stations that report surface and atmospheric observations and the software and hardware that make these observations available to road maintenance staff. However, the use of the term RWIS has expanded over time to mean an integrated system that includes detailed weather models and forecasts specifically tailored to the needs of road maintenance staff, in addition to public dissemination of travel-related road and weather condition information. The Federal Highway Administration (FHWA) is currently investing in research and development of even more sophisticated RWIS capabilities, referred to as Winter Maintenance Decision Support Systems. Each of these RWIS elements is briefly discussed below:

Sensor Stations

Nearly all of the more than 50 RWIS stations in Washington State are located along roadway right-of-way at locations, such as mountain passes and bridges, that typically experience the most severe weather-related road conditions. Figure 2-2 shows a

typical RWIS sensor station[5]. In some cases the location of these stations is determined specifically to fill gaps in statewide weather modeling.

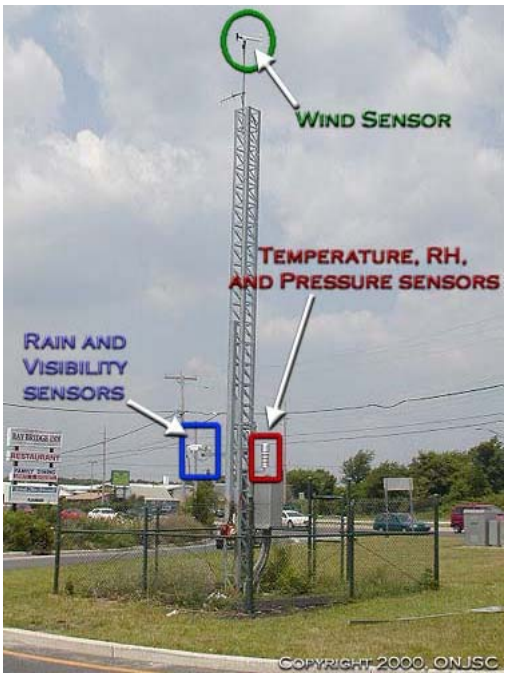


Figure 2-2: RWIS Sensor Station

The capabilities of these RWIS stations vary. In Washington, all provide air temperature, wind speed and direction detection; many provide road surface and subsurface temperatures; and some detect the presence and concentration of snow and ice control chemicals on the road surface. Many also have cameras, providing a visual image of the conditions at the site. These sensor stations make it possible to determine, on the basis of current conditions, things such as whether ice can exist, whether ice or snow will bond to the pavement, and whether frost can form at that site.

The North Central Region Winter Maintenance Plan calls for installation of up to 20 additional RWIS sensor stations over the next four years, at a total cost of $1.4 million

[5] Copyrighted by Office of the New Jersey State Climatologist. Used with permission.

for installation, training and maintenance, as part of efforts to further implement proactive winter maintenance practices (Boselly 2000a).

Communication Network

In the past it was common for maintenance staff to have dial-up access to a limited set of nearby RWIS stations. Recent hardware and software investments, as part of the rWeather program, have not only provided access to the statewide network of RWIS stations but also made the RWIS data easier to use through a service called SCAN Web[6]. The rWeather project has also integrated the data from the RWIS stations with nearly 400 other weather stations operated by other federal, state, and local agencies throughout the state. This integrated set of information is available on the rWeather website, making it possible for maintenance personnel and travelers alike to get a broad perspective on current weather conditions and forecasts throughout the state.

Weather and Pavement Temperature Modeling

The extensive network of weather stations described above supports highly detailed weather and pavement temperature computer modeling that in turn supports high-resolution forecasts. Working with the Northwest Regional Weather Consortium and the University of Washington Department of Atmospheric Sciences, the rWeather program has been able to further enhance a high-resolution computer model known as MM5 (mesoscale model version 5) that encompasses all of Washington. This model is run twice each day and has a resolution of 4 square kilometers (Brown 2000).

The rWeather program has also funded the development of a sophisticated pavement temperature model that calculates current and predicted road surface temperatures. Representations of these pavement temperatures are displayed on the rWeather website.

[6] SCAN Web is a trademark of Surface Systems, Inc.

Another tool that can be used for pavement temperature modeling is called thermal analysis. Thermal analysis requires that crews with specialized detection equipment go out and collect actual pavement temperatures along segments of highway in different weather conditions. This information is used to create temperature profiles for the highway that can be used to predict temperature pavement between sensor stations. Thermal analysis can also be used to determine the optimal location for RWIS sensor stations.

Thermal analysis has not been extensively used for forecasting pavement temperatures in Washington, which instead relies on highly sophisticated modeling techniques. However, a 2000 winter maintenance plan for the North Central Region recommends thermal analysis as a way to increase forecasting capability and thereby reduce winter maintenance costs (Boselly 2000a).

Tailored Weather and Pavement Temperature Forecasts

To be useful for winter maintenance operations, weather forecasts must be tailored to the needs of maintenance staff. They must be targeted to specific areas, and they must be focused on the weather conditions relevant to predicting road conditions. Specifically, weather forecasts must consider not only the predicted air temperatures but also road surface temperatures that will ultimately determine whether snow accumulates or black ice forms. NorthWest Weathernet, Inc., is an example of a private company that provides tailored weather forecasts under contract to some WSDOT maintenance areas.

A forecast tailored to winter road maintenance would indicate the type of precipitation to expect, how much to expect, where it will fall, when it will start, how long it will last, and whether it will "stick" to the road. Forecasts of this type are essential to cost-effective winter maintenance practices.

Even with sophisticated weather models and predictions, high quality forecasts are still the result of applying human judgment to computer-generated predictions.

Experience has shown that the highest success for tailored forecasts is achieved when the forecaster has an open line of communication with those who need to base decisions on those forecasts. rWeather program investments in weather data and modeling have contributed to improvements in the computer-generated predictions interpreted by the National Weather Service (NWS). NWS forecasts are made available to maintenance staff and the public on the rWeather website.

Traveler Information

Travelers informed about the potential for adverse driving conditions can take precautions that will increase not only the safety of their own trip but also the safety and mobility of other users of the highway system. Travelers who are not prepared to encounter significant snow accumulations, for example, can cause incidents that close or otherwise reduce the capacity of the highway. In Washington, the rWeather website provides statewide weather-related road condition reports and forecasts. Figure 2-3 shows an rWeather web site example of the pavement temperature and weather conditions forecast for a stretch of US Highway 2.

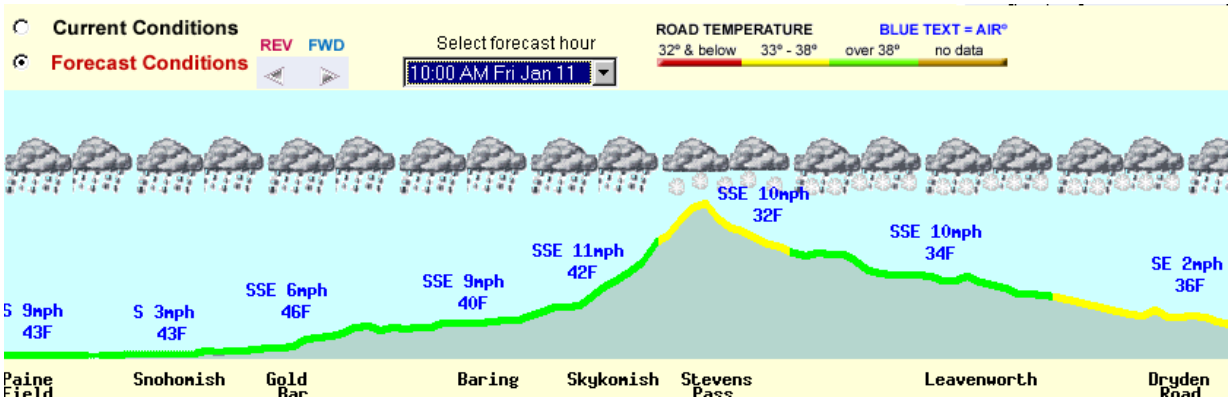


Figure 2-3: rWeather Pavement Temperature and Weather Forecast

Winter Maintenance Decision Support Systems

The FHWA's Decision Support Requirements initiative has generated a needs analysis, operation concept description, and preliminary interface requirements for a winter road Maintenance Decision Support System (MDSS). Current efforts are focused on developing a prototype with the intent to test it in partnership with state departments of transportation. It is expected that WSDOT will play a role in this testing activity. The objective of the MDSS is to take advantage of recent advances in weather forecasting and understanding of pavement temperature behavior to provide information tailored specifically to support proactive decision-making by winter road maintenance managers (FHWA 2001).

SECTION 3: RWIS BENEFITS

The potential benefits of a comprehensive and integrated RWIS are substantial. Investments in RWIS can provide travelers with better information for safe and efficient travel, provide information useful for efficient scheduling of maintenance personnel, enable maintenance personnel to cost-effectively provide a higher level of service, and provide higher quality observational data for improved weather forecasting. However, nearly all of these benefits result only when winter maintenance practices are significantly changed to take advantage of RWIS capabilities.

Many of the benefits of implementing these RWIS-enabled winter maintenance practices overlap; it is therefore useful to look at each practice individually to clarify the benefits that result from adoption of RWIS technologies.

PRACTICES ENABLED BY RWIS

Without detailed, tailored and targeted weather forecasts, winter maintenance decisions must be based on current weather conditions. According to SHRP research, highway maintenance organizations have traditionally reacted to current conditions, or at best a forecast of winter weather obtained from the media. Patrols are sent to check conditions, and supervisors are notified that roads have become icy or snow has begun to accumulate. Crews are sent out to attack the problems as they occur and stay on the job until the problems have subsided. “This reactive response can be costly in both time and materials” (Boselly 1993).

In contrast, the information available from a fully deployed RWIS makes it possible to adopt new, proactive ways of doing business that can more efficiently and cost-effectively provide safer conditions for the traveling public. The following beneficial winter maintenance practices enabled by RWIS have been identified and are discussed below and summarized in Table 3-1:

- Anti-icing
- Reduced use of routine patrols
- Cost-effective allocation of resources
- Provide travelers with better information
- Cost-effective summer maintenance scheduling
- Share weather data

Anti-icing

RWIS makes it possible for winter maintenance to be proactive. For example, the practice of anti-icing improves safety and mobility by keeping the road surface wet and slushy instead of icy. Anti-icing chemicals applied to the road surface either before or very early in a storm lower the temperature at which water freezes, prevent the bonding of snow, ice, or frost to the roadway. (Deicing, on the other hand, refers to using chemicals to break an existing bond between the roadway and ice or snow.) Preventing the bond of snow or ice to the roadway also allows the road to revert to bare pavement more quickly after a storm. Although anti-icing can be employed without RWIS, it is expensive because the costly deicing chemicals often get applied in excessive concentrations or when and where they are not needed. It is far more efficient and effective to implement anti-icing with the support of advanced road and weather information. The use of RWIS to support anti-icing operations results in lower material and labor costs, a higher level of service, less environmental impact, and improved safety than the reactive practices of plowing and sanding (Boselly 1993).

The key to a successful anti-icing strategy is knowing which chemical to use, in what amount, and when. RWIS provides the detailed and targeted weather forecasts to do that. Without site-specific and tailored weather information, many highway agencies wait until a storm hits to send out their work crews to salt, sand, and plow. By then the storm

already has the advantage, and maintenance crews struggle to keep up and to clear pavements that are already covered with snow or frost (Mergenmeier 1995).

Pavement temperature forecasts are critical to effective anti-icing. Even if snow is forecast to accumulate or is accumulating in some areas, if the pavement temperature is forecast to remain above freezing, chemical applications may not be necessary and plowing may not be required. In some cases, the most cost-effective decision is to do nothing (Boselly 1993).

Anti-icing requires less deicing material than that required to break the bond between the ice and the road later. Reduced amounts of sand and deicing chemicals provide cost savings and mitigate environmental damage. Roads that don't ice up to begin with don't require an application of sand for traction. Moreover, fewer labor hours are required for sand cleanup.

Reductions in the amount of sand used are especially desirable in air-quality non-attainment areas such as Spokane. In Oregon, the Department of Transportation found that 50 to 90 percent of the sand that is applied to pavements remains in the environment even after cleanup. Not only does the dust from road sanding operations contribute to air pollution, according to the United States Forest Service, sand sediment in streams and rivers is harmful to salmon (RoadSavers 1997).

In Washington, the North Central Region (NCR) has been expanding its use of anti-icing strategies over the last couple of years. Experience so far indicates that the region can increase the level of service it provides to the public (more time with roadways in the "bare" condition) at the same cost. Increased use of RWIS is expected to lower the cost of anti-icing because of the application of lower concentrations of chemicals, applying it at the right time, and in the right locations. In NCR's experience,

reductions in labor hours, equipment use, and the amount of sand that requires cleanup offsets the cost of the anti-icing program[7].

Because anti-icing prevents the buildup of ice and makes it easier to return roads to bare pavement condition after snow, anti-icing helps keep roadways at a higher level of service longer. Theoretically, as a result of alleviating exposure to unsafe conditions, mobility and safety are improved. Improved road conditions also enhance travelers' choices and support business and tourism activities, particularly in rural communities.

Note that other states have experienced significantly higher cost savings as a result of anti-icing because they are allowed to use brine, which is far less expensive than the anti-icing chemicals that can be used in Washington. It is also important to note that, despite improved conditions due to anti-icing, the North Central Region has received some negative public reaction to the practice. In February 2001, nearly 900 residents of the Methow Valley submitted a petition to the Secretary of Transportation's Office calling for an immediate end to use of liquid deicer for anti-icing operations.[8] The chemical used for anti-icing is mixed with an anti-corrosive agent that makes it brown, sticky, and hard to wash off. This is an advantage in keeping the anti-icer on road surfaces but it can be a great irritation to car owners. The anti-icing liquid is known to damage aluminum, a problem for wheels, other car components, trailers, and boats. In the North Central Region last winter, twelve people filed claims for damage. All were rejected. To date, WSDOT has maintained the position that the safety benefits of anti-icing far outweigh the inconveniences to drivers.[9]

Reduced Use of Routine Patrols

Accurate and timely weather observations from RWIS sensor stations at key locations can reduce the need for routine patrols, a common practice for monitoring or

[7] Conversation with Bob Stowe, Assistant Regional Administrator for Maintenance, North Central Region, January 22, 2001.
[8] Conversation, Jennette Ingham WSDOT Ombudsman, February 6, 2001.
[9] Conversation, Jeff Adamson, NCR Communications Manager, February 6, 2001.

detecting conditions of roads. This is particularly true if a camera is also located at the sensor station site. RWIS information can make patrolling unnecessary in normal snow and ice conditions and can provide warnings about high wind and heavy rain that are likely to cause hazardous roadway conditions. Some RWIS sensor sites in critical locations such as mountain passes also have cameras that provide images of current conditions. RWIS sensors and cameras become the eyes and ears of supervisors instead of exclusive use of routine road patrols. The result is lower equipment use costs and improved labor productivity. The only weather related reason to patrol becomes checking for downed trees or power lines or conducting other damage assessment activities (Boselly 1993).

Cost-Effective Allocation of Resources

A statewide survey conducted in 2000 measured customer satisfaction with WSDOT maintenance activities. Activities ranked as very important but for which customers expressed limited satisfaction included maintenance of roadway surfaces, pavement markings, drainage, and snow and ice removal (Pacific Rim Resources 2001). These results point to the need to allocate maintenance resources as effectively and as efficiently as possible.

RWIS can be used to optimize the allocation of labor, fleet, and material resources. Site-specific weather information and detailed weather and pavement condition forecasts make it possible to mobilize just the right amount of personnel and equipment at just the right time in just the right place to control snow and ice. Particularly within large geographic areas, this can greatly improve productivity.

"Call-outs" to personnel to deal with a storm event can be very expensive. Not only is call-out pay costly, but a minimum amount is guaranteed. RWIS sensor data and specialized forecasts make it possible to schedule staff for a storm or hold staff overtime, eliminating the need for call-out pay.

One of the benefits of RWIS already experienced in Washington is the ability to eliminate weekend and night shift work because of forecasts that make it possible to staff night and weekend shifts only when necessary. In the North Central Region, several shifts have been eliminated. Instead, all employees are assigned to the day shift, reportedly resulting in increased employee job satisfaction. There is no appreciable cost saving since the shift differential savings are likely to be offset by overtime costs. However, the assignment of all employees to the day shift greatly increases the department's ability to perform other maintenance work that can only be done with multi-person crews and during daylight hours. In this way, WSDOT is able to address in a timely way the backlog of maintenance activities that customers have identified as important. In some cases, the need for extra seasonal workers has been eliminated. Substantial snow and ice control cost savings could be achieved by entirely eliminating night shift positions.

Provide Travelers Better Information

A fully integrated and comprehensive RWIS includes information delivery mechanisms (including website, automated phone system, kiosks, highway advisory radio and variable message signs) that make it possible to disseminate important weather and road condition information to the traveling public. The assumption is that more informed travelers will make better decisions about where, when, and how to travel. The result is a safer driving environment for everyone during difficult conditions.

In Washington, the rWeather website is where RWIS information is made available to the public. The results of the rWeather on-line customer survey (see Section 5) indicate that travelers are using RWIS information to better prepare themselves for travel, presumably resulting in safer travel behavior. It is too early to tell whether providing access to this information (rWeather has only been in full production for one winter season) will actually improve safety as measured by a reduction in crashes,

injuries and fatalities in snow and ice conditions, but the rWeather users surveyed clearly indicated that they do feel safer as a result of having access to this information.

Cost-Effective Summer Maintenance Scheduling

Although directed primarily at winter maintenance operations, RWIS also can provide information that serves effective scheduling of maintenance crews during late spring, summer, and early autumn. Effective pavement marking and repaving operations need to be scheduled when road surface temperatures are conducive to getting the job done quickly and properly. By monitoring actual pavement temperatures, especially road surface temperature forecasts, maintenance crews can be scheduled accordingly.

The Wisconsin DOT reports that its pavement marking section and seal coat operations group use RWIS on a daily basis to determine work schedules (RoadSavers 1997). In Washington RWIS has not been reported to be used for this purpose. Although prediction of summer road temperatures in Washington is unlikely to be troublesome, the opportunity presented by RWIS may be the ability to start paving and pavement marking operations earlier in the spring and continue them later into autumn.

Share Weather Observation Data

Under the auspices of the rWeather project, WSDOT has become a participant in the Northwest Regional Weather Consortium, sharing RWIS data with weather observations collected by nine other local, state, and federal agencies (Brown 2000). The combined data are used to improve reporting of actual weather conditions and, perhaps more importantly, to improve the output of weather models and the ability of public and private forecasting services to provide more detailed and targeted weather forecasts. Theoretically at least, the more observational data, the better the weather models and the better the forecasts.

The RWIS sensor station network is especially important because it generates data for the road surface temperature modeling done by the University of Washington

Department of Atmospheric Sciences. Keeping the existing RWIS stations functioning properly and extending the network to additional locations will further improve the forecasted road surface temperatures that are critical to enabling proactive winter maintenance practices.

Table 3-1: Summary of RWIS-Enabled Winter Maintenance Practices and Benefits

RWIS-Enabled Practice	Associated Benefits
Anti-icing	• Lower material costs • Lower labor costs • Higher level of service (improved road conditions), travel time savings, and improved mobility • Improved safety (fewer crashes, injuries, fatalities, property damage) • Reduced equipment use hours and cost • Reduced sand cleanup required • Less environmental impact (reduced sand runoff, improved air quality) • Road surfaces returned to bare and wet more quickly • Safe and reliable access, improved mobility
Reduced Use of Routine Patrols	• Reduced equipment use hours and cost • Improved labor productivity
Cost-Effective Allocation of Resources	• Increased labor productivity • Reduced weekend and night shift work • Improved employee satisfaction • Reduced maintenance backlog • More timely road maintenance • Reduced labor pay hours • Overall higher level of service • More effective labor assignments
Provide Travelers Better Information	• Better prepared drivers • Safer travel behavior • Reduced travel during poor conditions • Fewer crashes, injuries, fatalities and property damage • Increased customer satisfaction and political support for WSDOT • Improved mobility • Safer, more reliable access
Cost-Effective Summer Maintenance Scheduling	• Higher labor productivity • Improved roadway surface
Share Weather Data	• Improved weather forecasts

CASE STUDIES

In Washington, the North Central Region reports benefits of anti-icing operations that are supported to some extent by RWIS. As mentioned in the previous section, these benefits are improved employee satisfaction and increased productivity as a result of eliminating most regular night shift assignments, as well as the ability to provide a higher level of service for the same cost. Many other states have reported similar benefits that have been documented as RoadSavers case studies.

As a follow-up to the SHRP program, FHWA's RoadSavers program contracted with the University of Nevada-Reno to coordinate and manage an assessment of the economic benefits of SHRP products, including RWIS and anti-icing. The first step involved collecting data on how state and local highway agencies were using SHRP products; this produced more than 100 case studies. Those case studies related to the use of RWIS and anti-icing are summarized in Table 3-2[10]. Case studies indicated particularly substantial cost savings can result from the implementation of both RWIS technology and an anti-icing strategy (Epps 1997).

Table 3-2: RoadSavers Case Studies as of July 10, 1997 (Anti-icing and RWIS)

Location	Reported Results
Kansas DOT	• Reduced bonding – snow removal faster & easier • Improved safety • Reduced use of chemicals • Less adverse environmental impact • Average savings $1600 per storm
Missouri DOT	• Clearer pavements, improved safety • Fewer chemicals, less environmental damage, saves money, less wear and tear on bridge decks and equipment • Labor and equipment savings

[10] Case studies can be found at http://www.fhwa.dot.gov/winter/roadsvr/casehome.htm.

Location	Reported Results
Oregon DOT	• RWIS helped ensure right time and place for chemicals based on pavement temperatures • Will save $7 million over 25 years due to reduction in chemicals, more efficient scheduling of crews, less damage to vegetation • Improved environmental quality • Safer, more reliable access to recreational areas
Maryland DOT	• Savings from reduced crew standby times expected to pay for the system in 5 to 7 years • Improved driving conditions • Lower costs for equipment and materials use and for labor expenses • Even greater improvements expected with anti-icing
California	• Safer roadway • More environmental protection • Reduced costs from lower requirement for staff, equipment and materials
Minnesota DOT	• Better idea of how much chemical to apply when cutting costs and minimizing environmental impacts • Return on investment of 200% to 1300%
Montana DOT	• Public benefits of faster response to weather-related emergencies • Better planned and executed maintenance activities • Reduced labor, material and energy costs • Enhanced road safety
North Dakota	• Efficient and effective winter maintenance strategies • Clearer and safer roads • Save money by applying deicing materials only when needed • Know when to impose load restrictions
Massachusetts Highway Department	• $53,000 savings in one winter • Reduced accident rates • Shorter travel times during winter storms • Reduced workplace absenteeism
Michigan DOT	• Improved safety • Reduced costs for crew time and chemical use • Reduced wear on equipment and bridge decks
Wisconsin DOT	• Clearer, safer roads • More efficient use of deicing materials • Increased awareness of anti-icing strategies • Lower cost for winter maintenance
Illinois DOT	• Able to respond at the right time in the right place with the right reaction • More efficient plowing and anti-icing operations and improved driving condition information improves safety Allows wiser use of salt and other material

Location	Reported Results
Iowa DOT	• Helps maintain ice-free roadways • Cuts down on labor costs • Reduces chemical use
West Virginia Parkways Authority	• Cost savings of $6500 per storm due to less salt and other materials • Paid for itself in one year • More efficient winter maintenance has improved highway safety
District of Columbia DPW	• Roads clearer of ice and snow • Use of deicing chemicals reduced • Determine where to do winter maintenance • Ensure safe driving conditions
New Jersey DOT	• Cut snow and ice control costs by 10 to 20 percent • Reduced use of salt and other chemicals • Roads clearer of snow and ice, improved travel conditions
Texas DOT	• Reduced winter maintenance costs • Improved service for motorists • Improved scheduling of highway construction work
Colorado DOT	• Improved scheduling of winter maintenance crews • Able to adopt anti-icing strategy that reduces sand use • Improved safety on mountain passes
South Dakota DOT	• Better safety, less material used and lower costs as a result of being more timely • Better scheduling of crews

BENEFIT/COST STUDIES

The literature offers no comprehensive benefit-cost studies of implemented RWIS programs in the North America. Furthermore, no large-scale RWIS systems have been fully incorporated into winter maintenance operations for many of the reasons outlined in the next section. However, several benefit/cost studies have been based on **expected** benefits in comparison to projected or actual costs.

The first significant benefit-cost modeling work was done by Boselly et. al. as part of the SHRP program (Boselly 1993). In fact the report projected results specifically for Washington State, indicating a benefit/cost ratio of 5.0 due primarily to the

assumption that improved weather information would eliminate the need for routine road patrols (and the associated labor and equipment hours).

Boselly refers to his model as a “cost-reduction simulation model.” "Cost reductions" are defined as the difference in direct snow and ice control expenditures produced by alternative RWIS options, and the costs required to implement various the RWIS options. An important finding was that the winter maintenance cost reductions due to RWIS sensor stations and pavement temperature models used by themselves are significantly lower than those that can be achieved by using detailed weather and pavement condition forecasts to mobilize resources before snow and ice problems accumulate. Furthermore, the most cost-effective reason for using forecast information is to take no action.

Somewhat more recently, a life cycle benefit/cost model for RWIS was developed at the University of Texas and applied as a case study for an RWIS station planned in Abilene, Texas (McKeever 1998). The model resulted in a net present worth for the planned RWIS station of $900,000 over a 50-year period.

The McKeever model was based on a synthesis of previous RWIS benefit/cost work, as well as data collected from various agencies. Like the Boselly model, it was based on some significant assumptions, including the elimination of routine patrols and the associated labor and equipment costs, and reducing labor hours by 15 percent for each storm event as a result of reducing the number of passes required to clear the roadway. On the basis of findings from other studies, McKeever assumed that reductions in liability expense, pollution costs, and travel delay costs would be negligible in comparison to other RWIS costs and savings. However, McKeever did assume a reduction in fatal, injury, and property damage accidents, given the assumption of reduced exposure to snow and ice conditions as a result of RWIS.

More recently a draft benefit/cost study of RWIS and anti-icing technologies attempted to document benefits experienced by states involved in early testing of RWIS

and anti-icing. Most states reported snow and ice control efficiencies (primarily based on employee feedback) but little in the way of documented dollar savings (Boselly 2000b). The findings indicated that the lack of a formal methodology for documenting savings and annual variability made the task even more difficult. Reports were found of site-specific accident reductions (although some increase in severity due to higher speeds), reductions in overtime, virtual elimination of sand disposal costs, and fewer road closures.

The North Central Region Winter Maintenance Plan includes a high-level benefit/cost analysis for that region. The plan notes that "forecasts have the potential for the highest return on the investment if precision in the forecasts can be established." The North Central Region plan assumes a 10 percent savings in direct snow and ice control expenditures, merely citing that such an estimate has been used elsewhere. On the basis of this assumption, a benefit/cost ratio of 1.4 is projected over four years. The plan further assumes that the addition of thermal mapping would reduce the number of RWIS stations needed and thereby increase the benefit/cost ratio to 1.6. An increase in forecasting capability could push the cost/benefit ratio to 2.0. With continued expansion of the RWIS program, the plan projects a $2,500,000 savings over ten years (Boselly 2000a).

RESULTS IN WASHINGTON STATE

WSDOT's North Central Region has led the state in terms of adopting anti-icing and using tailored weather forecasts. As part of the draft study report mentioned above (Boselly 2000b), Washington's North Central Region's maintenance staff reported the following at the end of the winter of 1999/2000:

- Less sand used (70 percent less reported in Wenatchee, resulting in a savings of $23,000)
- Eliminated sand cleanup in some areas

- Less guardrail damage
- Eliminated weekend work, saved call-out and overtime on weekends and holidays, and freed personnel to do other work in some areas
- Lower accident rate
- Fewer tort claims
- Better level of service
- Fewer equipment hours
- Positive feedback from the public
- "Happier environmentalists"

RWIS-supported changes in snow and ice control practices are still too new to have achieved consistent region-wide application and to demonstrate clear trends. A review of maintenance expenditures and accident records reveals no clear evidence that these benefits are substantial enough to be detected in cost figures for snow and ice control. The number of accidents, in particular, is highly variable, with no clear trends visible in the short term. Region management has stressed that the most significant result to date has been an increase in the level of service offered to the public without an increase in cost[11].

Snow and Ice Control Expenditures

RWIS-supported changes in snow and ice control practices are still too new to have achieved consistent region-wide application and to demonstrate any clear trends. A review of maintenance expenditures and accident records reveals no clear evidence that these benefits are substantial enough to be detected in cost figures for snow and ice control. This analysis is complicated by limited weather condition information and a current lack of level of service measurements. (The lack of level of service information is

[11] Conversation with Bob Stowe, Assistant Regional Administrator for Maintenance, North Central Region, January 22, 2001.

being addressed by incorporation of winter maintenance into the Maintenance Accountability Process discussed at the end of this section.)

WSDOT uses a "winter frost index" to reflect the severity of each winter and compare conditions from region to region and from year to year. WSDOT set out to use the Winter Index developed by the Strategic Highway Research Program, however the winter index calculation requires statewide snowfall data, which is not available for Washington State. As a surrogate measure, the frost index was developed and analysis showed a good correlation with the winter index. The frost index is calculated from temperature observations provided by the National Weather Service (Baroga 2000).

Figure 3-1 shows the frost index for the last four winters only for the three regions with the highest winter maintenance expenses. (The North Central Region, South Central Region and Eastern Region account for 70 percent of total snow and ice control costs in the last four years.). The index uses a scale from –50 to 50, with –50 being the most severe[12] In the following figure the scale has been reversed so that more severe winters show as higher on the chart than less severe winters.

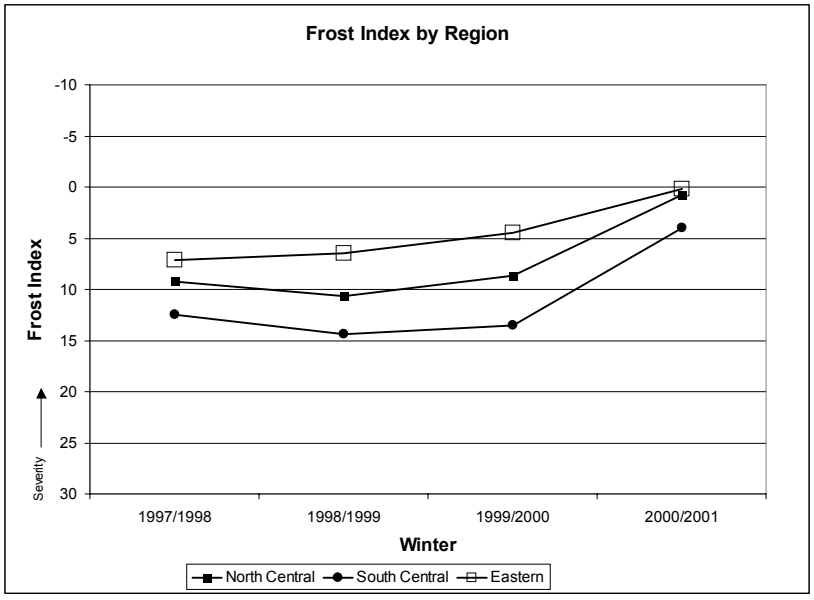


Figure 3-1: Winter Frost Index

[12] Frost index information provided by Mike Ellis, WSDOT Maintenance Office 10/22/01.

As shown in Figure 3-1, the frost index for the last four years for the three regions shows the same pattern at different levels of severity.

Snow and ice control costs for the same three regions are shown in figures 3-2 through 3-4[13]. Without snowfall and level of performance information it is difficult to draw conclusions from the expense data. Trends should begin to show themselves more clearly after two or three more winters. It does appear that there may be already some leveling off of material and equipment costs in the North Central Region, which uses anti-icing strategies extensively[14].

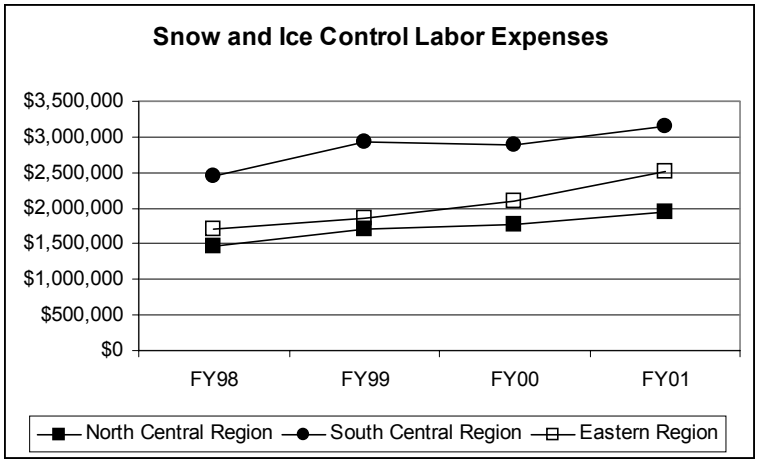


Figure 3-2: Snow and Ice Labor Cost

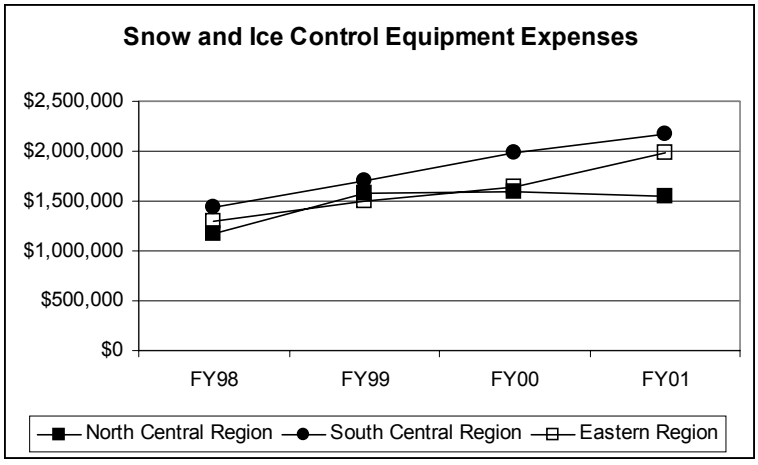


Figure 3-3: Snow and Ice Equipment Cost

[13] Snow and ice control expenses provided by Lee Wlazlak, WSDOT.
[14] Per Jack Manicke, WSDOT Maintenance Office, test de-icing materials and stock pile maintenance used in the Eastern Region during the FY'01winter resulted in substantially lower materials cost.

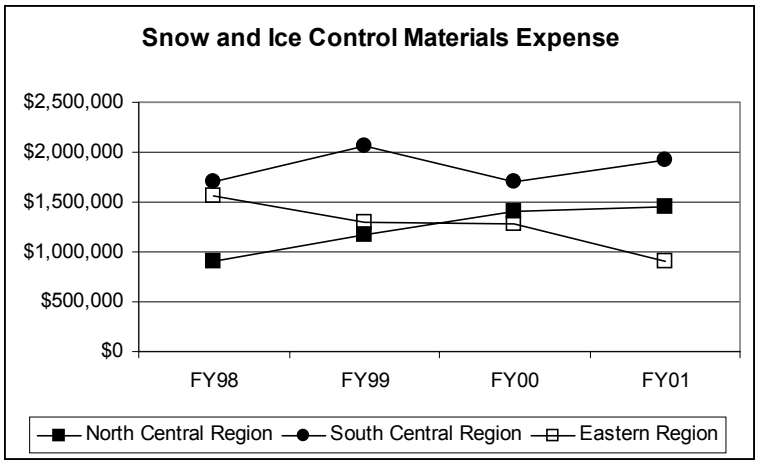


Figure 3-4: Snow and Ice Materials Cost

Safety

Accident data are reported by calendar year, so it is difficult at this time to see any accident trends as a result of anti-icing operations. Regardless, accident numbers are highly variable and with only one year of extensive use, it is too early to see any definitive evidence that anti-icing has reduced accidents. A further impediment to the analysis is that data on vehicle miles traveled during ice and snow conditions are not available, making it impossible to calculate accident rates. For the North Central Region and the South Central Region, figures 3-5 and 3-6 show the number of injury accidents and fatal accidents that occurred in conditions of snow and ice[15]. Accident data are not available for 1997 and 1998.

[15] Accident data provided by Kathy Tanner, Transportation Data Office

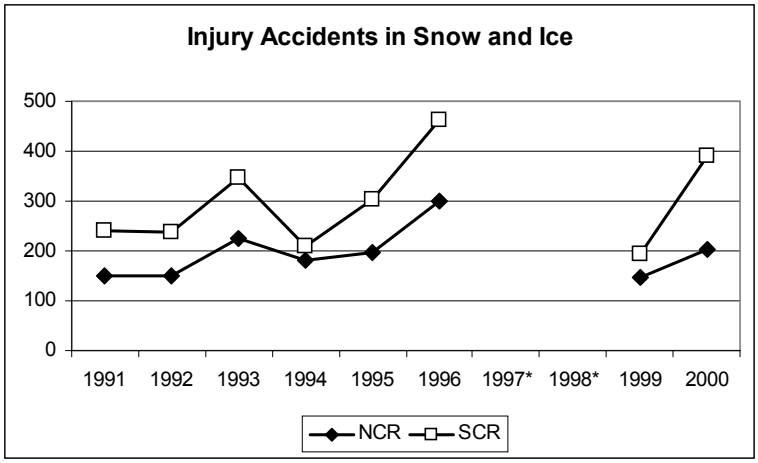


Figure 3-5: Injury Accidents

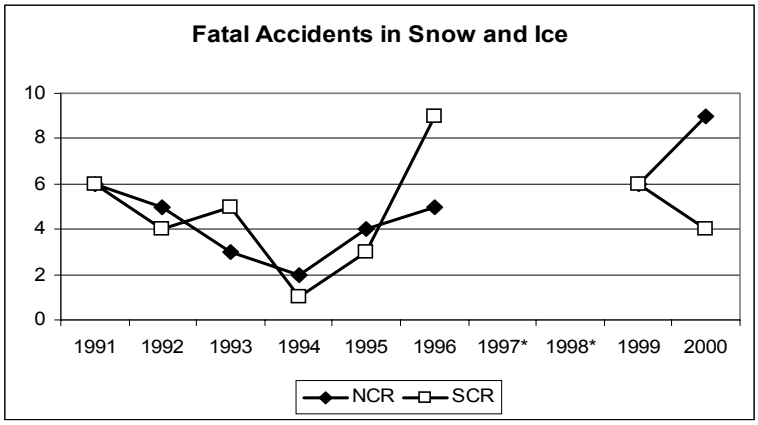


Figure 3-6: Fatal Accidents

Level of Service Performance Measures

WSDOT has been pilot testing a method of measuring snow and ice control performance for the past two winters and has made final recommendations for incorporating these measures into the Maintenance Accountability Process (MAP). When implemented, the new performance measurement technique should provide some very useful information, particularly with respect to the level of service outcomes for anti-icing and sanding strategies. It will also then be possible to compare level of service performance with snow and ice control expenditures.

SECTION 4: MAINTENANCE PERSONNEL SURVEY

WSDOT maintenance personnel were surveyed during May and June of 2001 about their use of, and attitudes toward, various sources of road weather information. Questionnaires were mailed to all 24 maintenance area superintendents with instructions to complete the questionnaire themselves and distribute copies of it to supervisors and lead technicians within their area. A copy of the questionnaire and a summary of the responses are included in Appendix A.

A total of 129 questionnaires were received, overall a 51 percent return rate. Supervisory staff (superintendents and supervisors) had a higher return rate than lead technicians and some WSDOT regions had much higher return rates than others as shown in Figure 4-1. Forty-four percent of the respondents were superintendents or supervisors and 56 percent were lead technicians. Responses were received from every WSDOT region although the Southwest Region was poorly represented with a response rate of only 17 percent. As a result, throughout this report responses from the Southwest Region are included in statewide results but not shown in comparison with results from other regions.

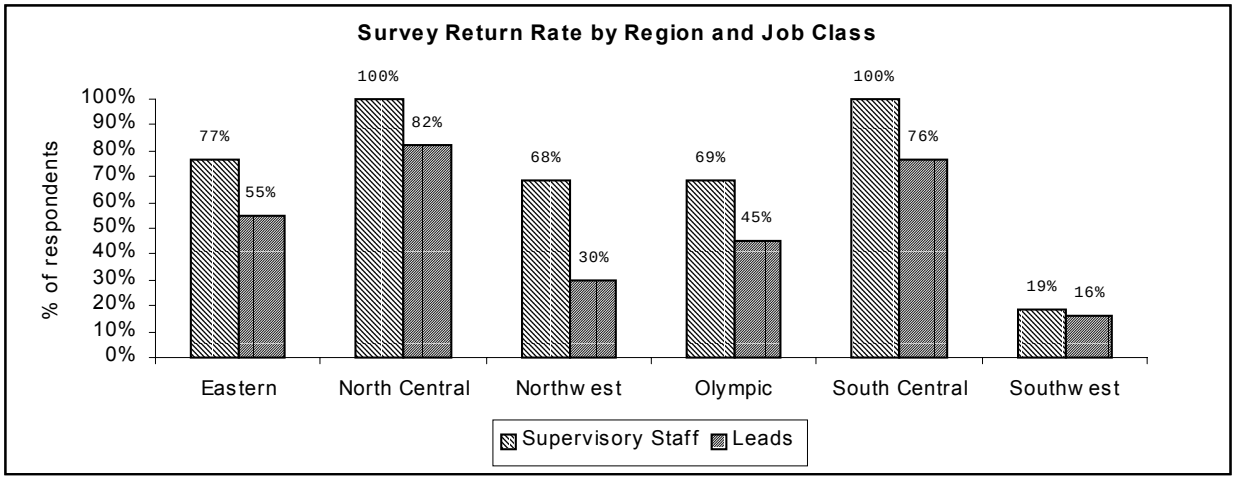


Figure 4-1: Survey Return Rates by Region and Job Class

WINTER MAINTENANCE

Winter Maintenance Issues

Supervisory staff (superintendents and supervisors) were asked to indicate their first and second most common winter maintenance issues. The most common winter maintenance issues were black ice (first or second most common for 66%), followed closely by frost (63%), as shown in Figure 4-2. Snow accumulation was ranked as either the first or second most common winter maintenance issue by 43 percent of the supervisory staff respondents. Not surprisingly, the most common winter maintenance issues varied considerably by region. For the Eastern Region, frost was reported as the most common winter maintenance issue. In the North Central Region the issue was frost and snow accumulation. In the South Central Region it was snow accumulation and in the Northwest and Olympic regions it was black ice.

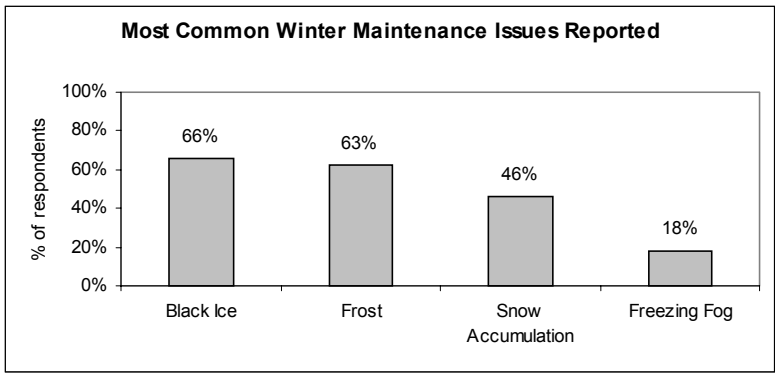


Figure 4-2: Most Common Winter Maintenance Issues

Snow and Ice Control Practices

Supervisory personnel were asked how extensively they used each of the following snow and ice control practices during the 2000/2001 winter season: patrols, plowing and sanding, anti-icing (to prevent an ice/road bond), and de-icing (to break an ice/road bond). As shown in Figure 4-3, patrols were used extensively by nearly half of

the respondents. About one third reported using anti-icing or plowing and sanding extensively, and less than 15 percent reported using de-icing extensively. Use of these techniques varied considerably by region, as shown in Figure 4-4.

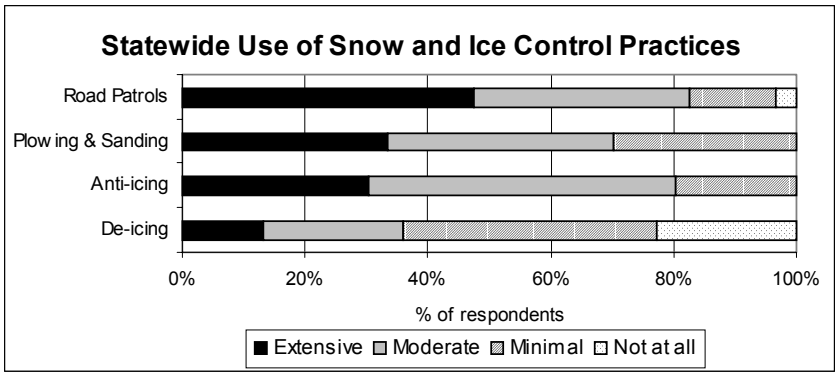


Figure 4-3: Statewide Use of Snow and Ice Control Practices

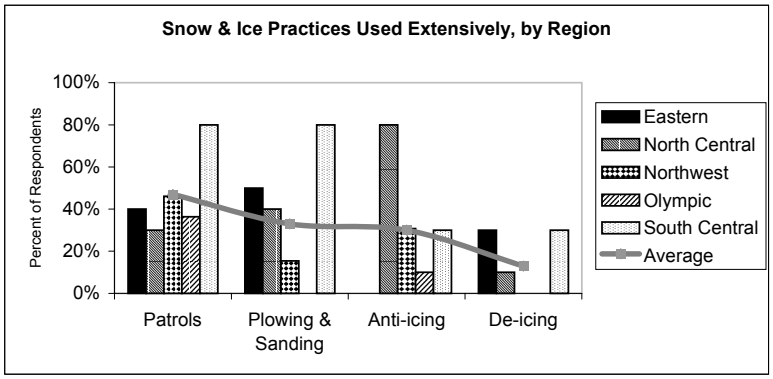


Figure 4-4: Snow and Ice Practices Used Extensively, by Region

WEATHER INFORMATION

Weather Information Sources

Respondents were asked to indicate how frequently they consulted various sources of weather information to make snow and ice control decisions. Figure 4-5 indicates the number of respondents who answered that they consulted a particular source of information on either a daily or weekly basis. Overall, the most used weather

information resources were routine road patrol reports, local broadcast TV, local broadcast radio, and the Internet/Web.

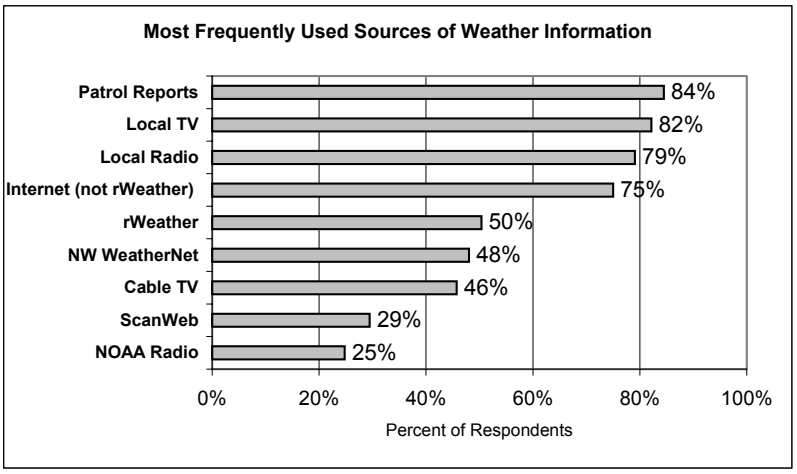


Figure 4-5: Most Frequently Used Sources of Weather Information

Supervisory staff were more likely to rely on less traditional sources of information than were lead techs, as shown in Figure 4-6. Twice as many supervisory staff as lead techs use SCAN Web, and more than twice as many supervisory staff as lead techs used rWeather.

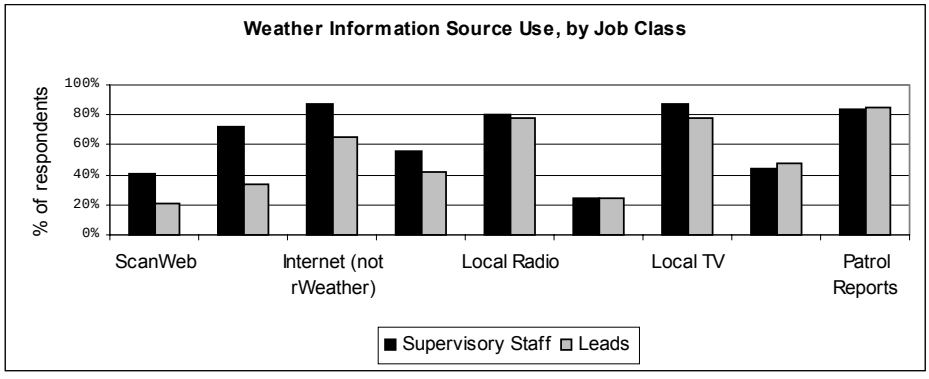


Figure 4-6: Weather Information Source Use, by Job Class

Figure 4-7 shows that private sector weather forecasting services were used more in the North Central Region than in any other region. The North Central Region also

reported using rWeather more than the other regions. The Eastern Region used SCAN Web much less frequently than any other region[16].

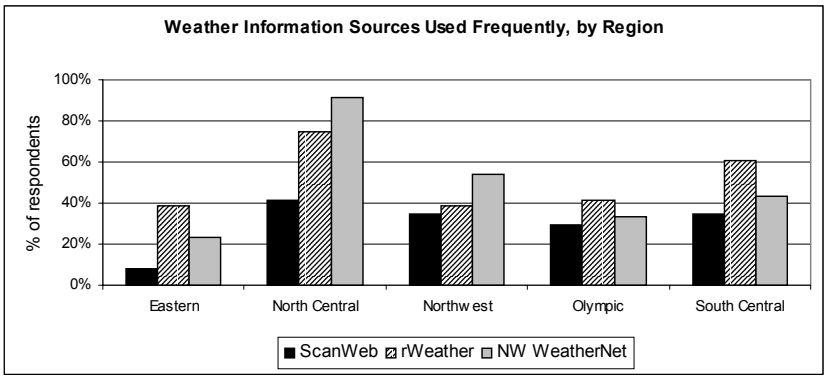


Figure 4-7: Weather Information Sources Used Frequently, by Region

Respondents who reported using anti-icing extensively also reported relying on NorthWest Weathernet and SCAN Web more than those who reported extensive use of plowing and sanding and little or no use of anti-icing, as shown in Figure 4-8.

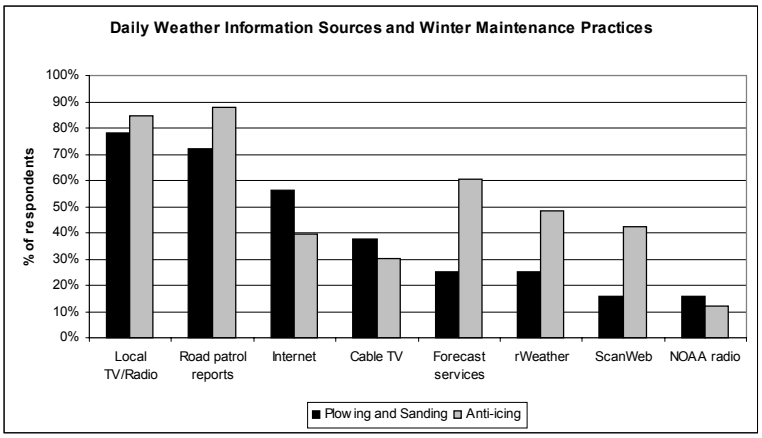


Figure 4-8: Daily Weather Information Sources and Winter Maintenance Practices

Nearly half (46%) of the respondents consulted road patrol reports from outside of their own maintenance areas and 20 percent consulted SCAN Web for RWIS stations

[16] According to Bill Brown, RWIS Program Manager this is due to the limited availability of SCAN Web in the Eastern Region during the 2000/2001 winter season.

outside of their areas. Use of these external resources varied by region, with the Olympic Region using external road patrol reports the least and the North Central Region making the most use of SCAN Web for external RWIS sites (see Figure 4-9).

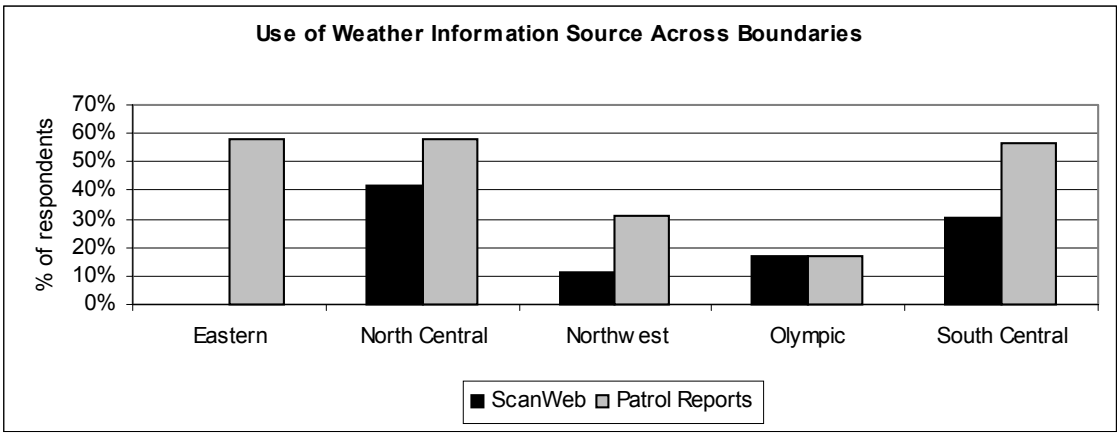


Figure 4-9: Use of Weather Information Sources Across Boundaries

Internet Websites Used for Weather Information

Just over three quarters (77%) of the respondents indicated that they used at least one Internet website on a daily or weekly basis for weather information. The National Weather Service was used most often (by just over half of the respondents), followed by WSDOT's rWeather website, as shown in Figure 4-10. The Weather Channel website is used by 36 percent of the respondents, and nearly 40 percent indicated that they used some other Internet website for weather information.

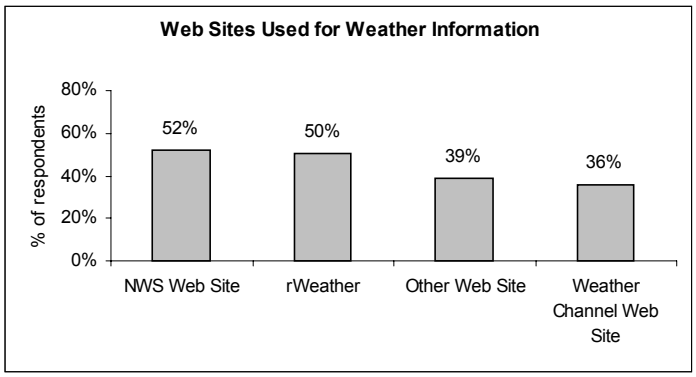


Figure 4-10: Websites Used for Weather Information

Satisfaction with Available Weather Information

Figure 4-11 shows that just over 65 percent of respondents indicated that they were very or generally satisfied with the weather information they had available for winter maintenance decisions during the winter of 2000/2001. An additional 20 percent indicated that they were somewhat satisfied. Only 2 percent indicated that they were not at all satisfied with the weather information they had available to them.

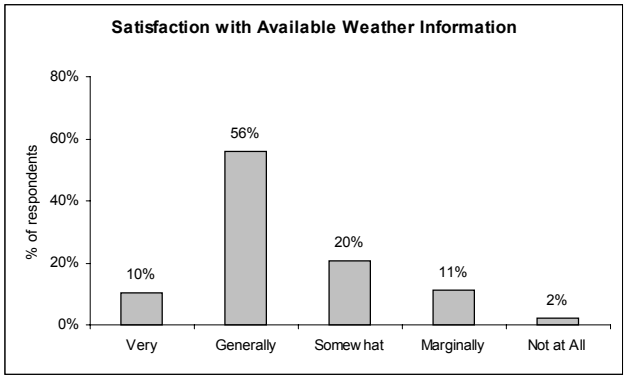


Figure 4-11: Satisfaction with Available Weather Information

Respondents in the Eastern and North Central regions indicated a slightly lower level of satisfaction with the weather information they had available to make winter

maintenance decisions than in the South Central, Olympic, and Northwest regions (see Figure 4-12).

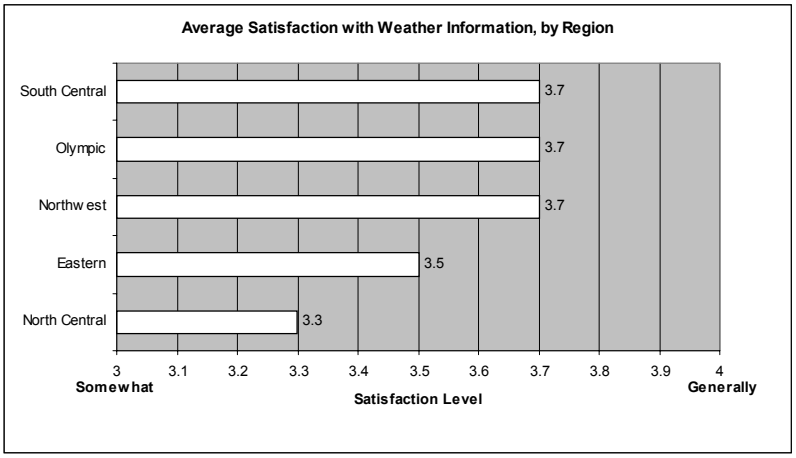


Figure 4-12: Average Satisfaction with Weather Information, by Region

Savings from Detailed Weather Information

Respondents were asked whether they had experienced any of a list of savings as a result of the use of detailed weather information. More efficient use of labor was cited by nearly 65 percent of supervisory staff. Between 40 and 50 percent of supervisory staff also indicated that they had experienced labor hour and equipment hour reductions and lower material costs. Ten percent indicated that they had not experienced any of these benefits (see Figure 4-13).

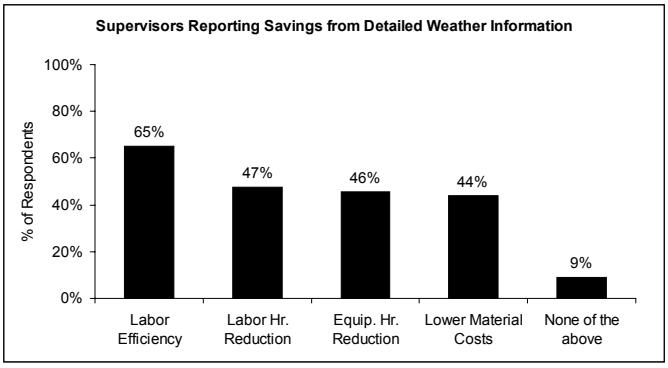


Figure 4-13: Savings from Detailed Weather Information, by Job Class

Savings experienced varied by region, with labor efficiency reported more often by the Northwest and North Central regions, labor hour reductions reported more often by the North Central and Olympic regions, equipment hour reductions reported more often by the North Central Region and lower material costs reported more often by the Olympic Region (see Figure 4-14).

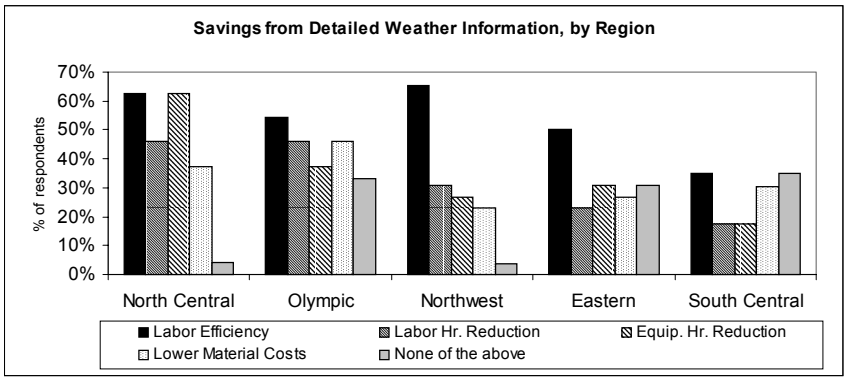


Figure 4-14: Savings from Detailed Weather Information, by Region

Improvements to Weather Information

Respondents were asked which improvements to the weather information they received would be valuable to them. Figure 4-15 shows that improved reliability and more detailed forecasts targeted to specific areas topped the list of valuable improvements.

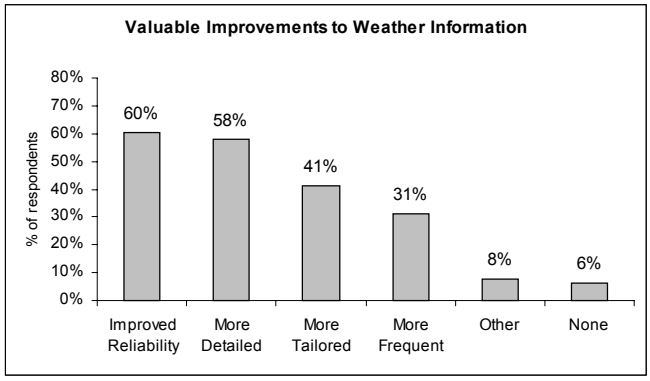


Figure 4-15: Valuable Improvements to Weather Information

Potential to Reduce Routine Patrols and Increase Anti-icing

Reducing routine road patrols and increasing the use of anti-icing strategies are the two primary ways that RWIS can generate safety and cost effectiveness benefits for WSDOT. More (73%) respondents reported the potential for improved weather information to increase the use of anti-icing than those (43%) who reported its potential to reduce routine road patrols. Supervisory staff were more likely than lead techs to expect these outcomes, especially regarding routine patrols. Results varied by region as well, with the North Central and Olympic regions seeing the most potential and the Northwest and Eastern regions seeing the least (see figures 4-16 and 4-17).

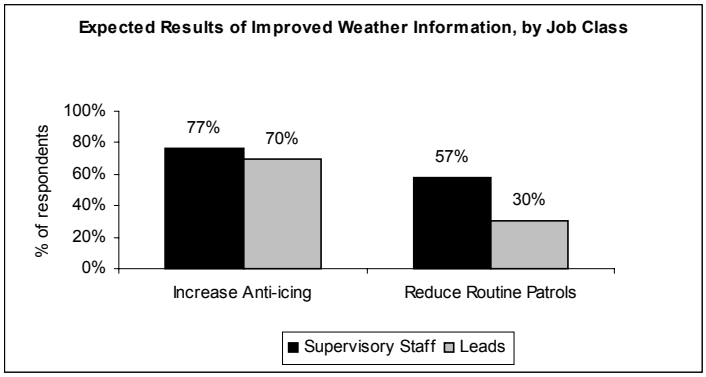


Figure 4-16: Expected Results of Improved Weather Information, by Job Class

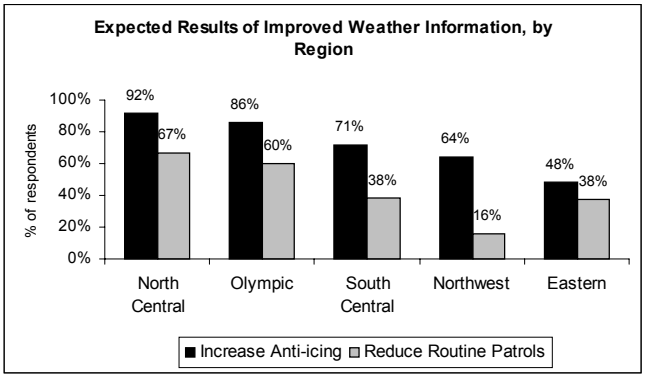


Figure 4-17: Expected Results of Improved Weather Information, by Region

Weather Information Source Ratings

Respondents were asked to rate SCAN Web, the rWeather website and weather forecasting services such as NorthWest Weathernet in terms of ease of use, usefulness for making maintenance decisions, and level of confidence in the information. All sources of weather information ranked at medium or just below in terms of level of confidence in the information. In terms of ease of use and usefulness, forecasting services ranked the highest, as shown in Figure 4-18.

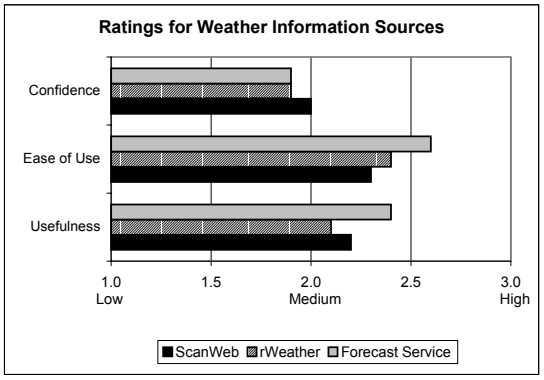


Figure 4-18: Ratings for Weather Information Sources

Usefulness of Information for Winter Maintenance Decisions

Respondents were asked to indicate how useful each of several site-specific types of information (many of which are available from RWIS sensor stations) are for making snow and ice control decisions. The results are shown in Figure 4-19. Nearly all respondents reported that road condition (icy, wet, etc.) was very or somewhat useful information. Of interest is the fact that most of the pieces of information available from RWIS stations were viewed as very useful by only about 40 percent of the respondents. Surprisingly, camera images were viewed as not useful by nearly 30 percent of the respondents.

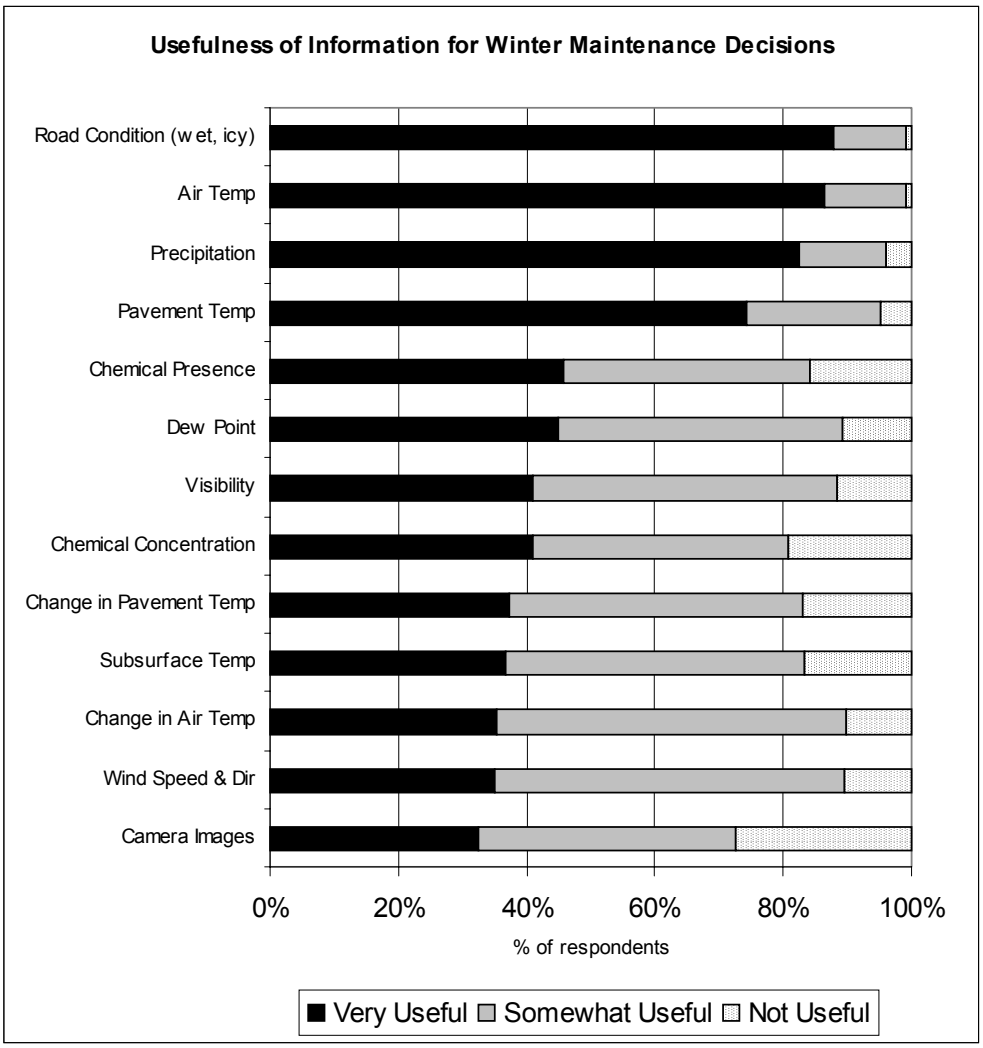


Figure 4-19: Usefulness of Information for Winter Maintenance Decisions

Internet Access

One hundred percent of the supervisory staff responding to the survey reported having Internet access at work. In contrast, less than 70 percent of the lead tech personnel reported having Internet access at work. The North Central and Northwest regions had the highest percent of lead techs with access (86% and 85%). The Eastern Region had the lowest rate of Internet access, with only 40 percent of lead techs reporting having access at work (see Figure 4-20).

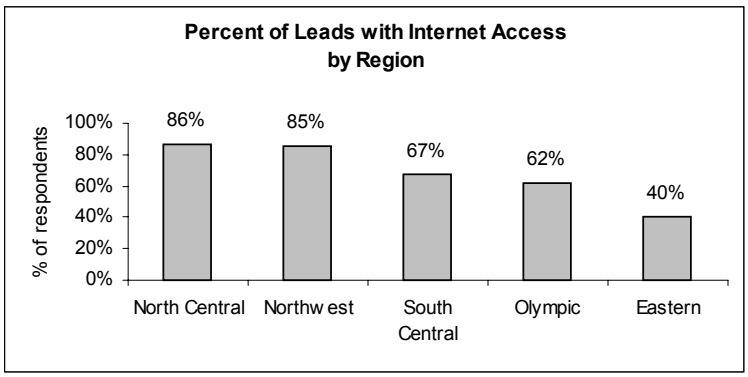


Figure 4-20: Lead Techs with Internet Access, by Region

Comfort with Internet and Pagers

Respondents were asked to indicate how comfortable they were at getting information from the Internet and text message pagers. Of those who had used these technologies, nearly half reported being very comfortable with both. However, 16 percent indicated that they were not at all comfortable getting information from pagers, while only 1 percent indicated the same about the Internet (see Figure 4-21).

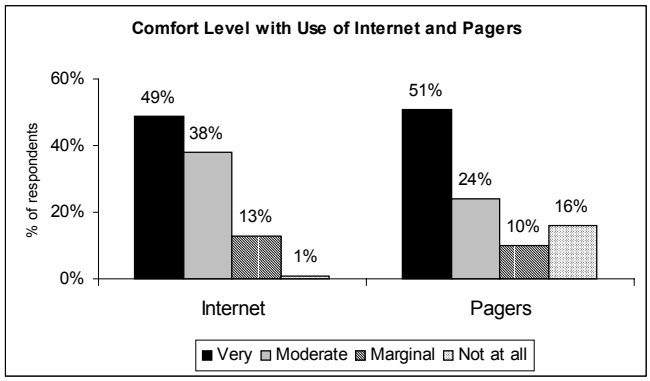


Figure 4-21: Comfort Level with Internet and Pagers

As shown in Figure 4-22, nearly twice as many supervisory staff as lead techs reported being very comfortable using the Internet; however just over one quarter of the lead tech staff had never used the Internet.

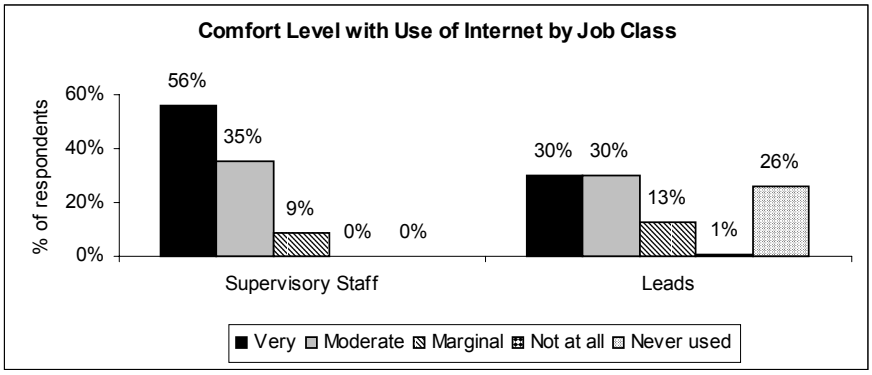


Figure 4-22: Comfort Level with Internet, by Job Class

Adequacy of Training

Most (74 percent) of the respondents who had received training in interpreting weather information reported that the training was adequate for making snow and ice control decisions. However, more than half (54 percent) indicated that they had not had any training in interpreting weather information at all. Just over 60 percent of lead techs reported having received no weather interpretation training along with 45 percent of the supervisory staff respondents. Most of those reporting that they had not received training were from the Eastern Region. Those most likely to have received training were from the North Central Region (see figures 4-23 and 4-24).

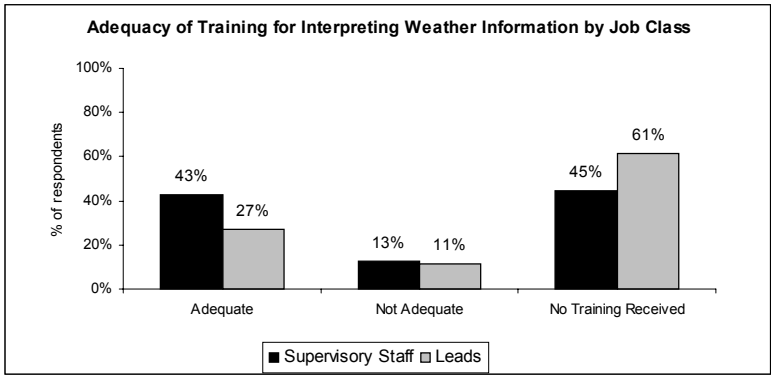


Figure 4-23: Adequacy of Training, by Job Class

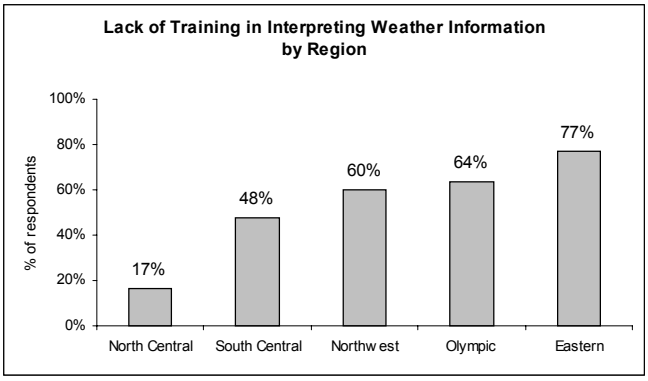


Figure 4-24: Lack of Training, by Region

RWIS STATIONS

Satisfaction with RWIS

Forty-one respondents indicated that they had an RWIS sensor station in their maintenance area. These respondents were asked to indicate their satisfaction level with RWIS data accuracy, location of existing stations, equipment reliability, and availability of training. The results are shown in figures 4-25 through 4-27. The majority of respondents indicated that they were only somewhat satisfied with these RWIS aspects. Respondents from the Eastern Region indicated the highest dissatisfaction with these aspects of RWIS, with a full 50 percent indicating they were not at all satisfied with RWIS equipment reliability and data accuracy. Among those with RWIS stations, satisfaction with RWIS training varied considerably by region, as shown in the adjacent chart. Half or more of the respondents in the Eastern, Northwest, and South Central regions indicated that they were not at all satisfied with the availability of RWIS training. Satisfaction with the availability of training also varied somewhat by job class, with nearly half of lead techs indicating they were not at all satisfied.

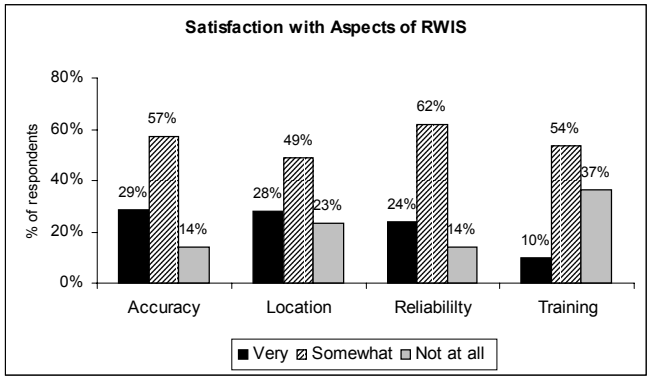


Figure 4-25: Satisfaction with RWIS Stations

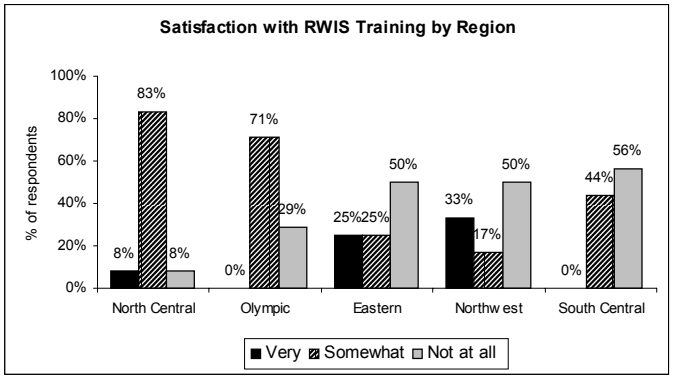


Figure 4-26: Satisfaction with RWIS Training, by Region

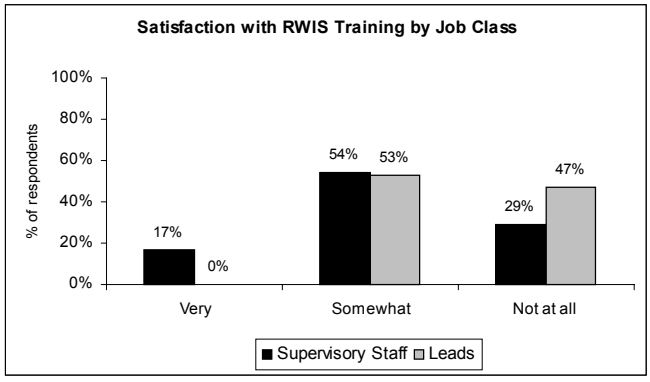


Figure 4-27: Satisfaction with RWIS Training, by Job Class

Of those respondents with an RWIS station in their area, a majority (56%) indicated that they did not use SCAN Web; however this percentage varied considerably by region, as shown in Figure 4-28. Respondents with RWIS stations in the South Central and North Central regions reported using SCAN Web twice as often as those in the Olympic and Northwest regions. Less than 20 percent of the respondents in the Eastern Region reported using SCAN Web if they had an RWIS station in their area.[17]

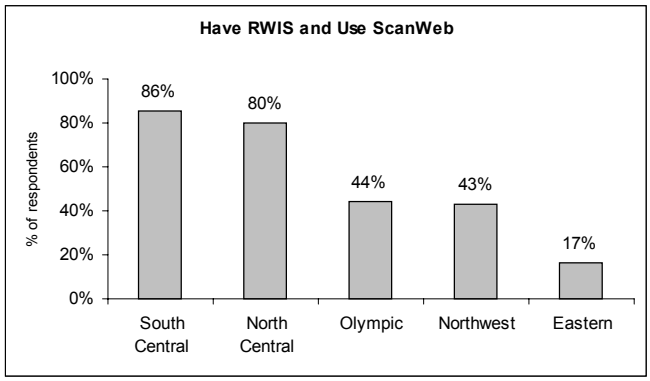


Figure 4-28: Have RWIS and Use SCAN Web

Additional RWIS Stations

The results of the survey indicate extensive support for additional RWIS stations. Overall, 84 percent indicated that additional RWIS stations in their maintenance area would be useful in making snow and ice control decisions. Support varied by region, as shown in Figure 4-29.

[17]According to Bill Brown, RWIS Program Manager this is due to limited availability of ScanWeb in the Eastern Region during the 2000/2001 winter season.

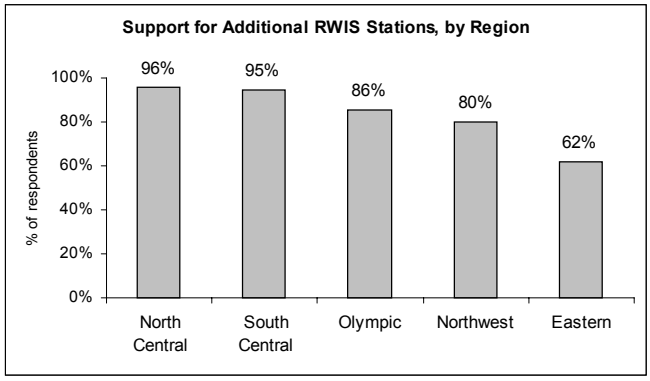


Figure 4-29: Support for Additional RWIS, by Region

RWEATHER

Overall, 79 percent of the respondents indicated that they were aware of the rWeather website, and of those, 78 percent had used it. Awareness and use varied by region and job class, as shown in figures 4-30 and 4-31, with awareness and usability highest in the North Central and South Central regions and among supervisory staff.

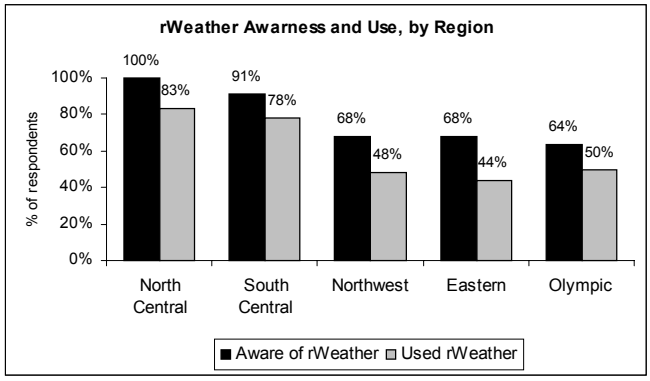


Figure 4-30: rWeather Awareness and Use, by Region

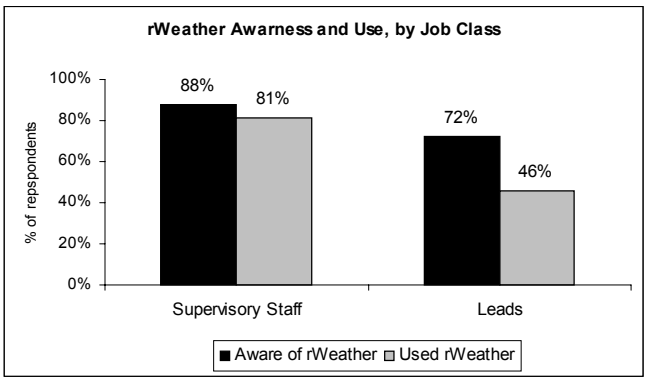


Figure 4-31: rWeather Awareness and Use, by Job Class

National Weather Service warnings, satellite and radar images, and the statewide weather map were cited as the most valuable features of rWeather. Nine of the ten statewide features were rated as very useful or somewhat useful by over half of the respondents. Of concern is that less than half of the respondents viewed pavement temperature features as useful. Since pavement temperatures are key to winter maintenance decisions, this suggests that emphasis should be placed on training related to the credibility and usefulness of this information (see Figure 4-32).

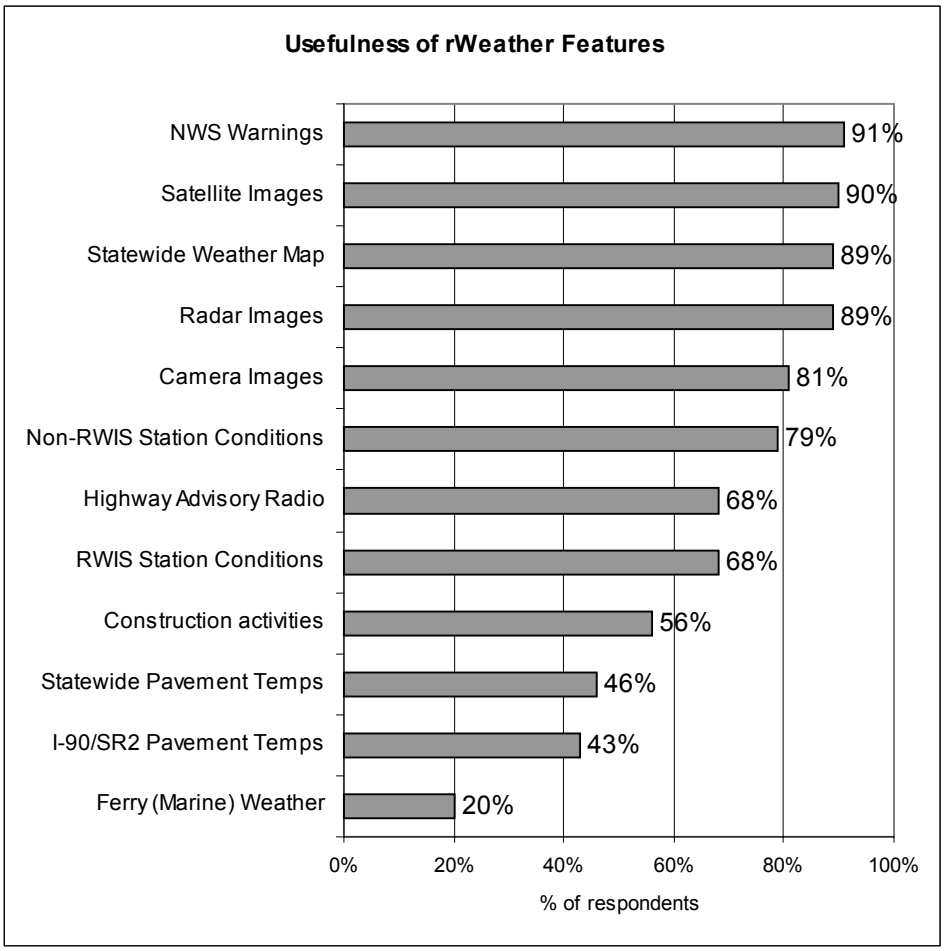


Figure 4-32: Usefulness of rWeather Features

ADDITIONAL ROAD WEATHER INFORMATION INVESTMENTS

Respondents were asked to indicate the RWIS-related activities in which they would like to see WSDOT invest additional resources. The results are shown in Figure 4-33. Two of three activities most often selected for additional investment were related to training. Nearly 70 percent indicated that they would like to see more investment in training related to interpreting weather data. Additional RWIS stations and training related to anti-icing strategies were cited by just about half of the respondents. Additional resources for RWIS station maintenance and operations and additional investment in

providing weather and road condition information to the public followed at more than 40 percent. Less than one quarter of the respondents requested improved Internet access and additional office computers. Although low, this number reflects that access to computers and the Internet is a priority for those who do not already have it.

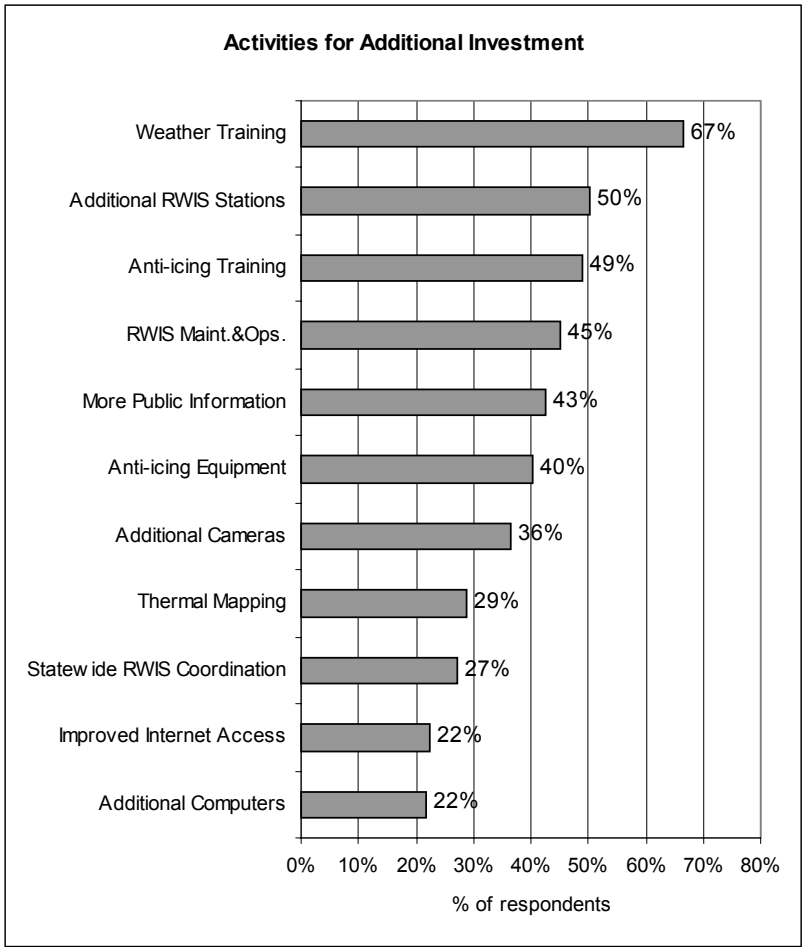


Figure 4-33: Activities for Additional Investment

Comments

Sixty of the respondents (46%) shared additional comments about weather information and winter maintenance decision–making. These comments (a copy of which can be found in the questionnaire example in Appendix A) can be categorized as shown in Table 4-1.

Table 4-1: Maintenance Survey Comments

Comment Summary	Number of Comments
Improvements in forecast reliability are essential in order to use forecasts for winter maintenance decision-making.	8
Additional computers and Internet access are necessary in order to take advantage of weather information resources.	8
Support for the importance of advanced road weather information.	8
Having a good forecast is not enough; road patrols are necessary for responsible decision-making.	8
Miscellaneous	8
RWIS information is inaccurate or not timely.	6
Additional training is necessary.	5
Need improved road condition information for the public.	3
Winter maintenance staffing is inadequate.	2
In this region an accurate enough forecast is not possible.	2
Additional camera sites are needed.	2

The following comments are representative of the comments in the first four categories:

> "At Pullman we just go out over the sections if there is any question of frost or worse. After taking care of the same sections for 23 winters you begin to see a pattern in areas that are hardest hit so you just naturally check them. For instance, in Pullman you might have clear skies but south of downtown it could be 6" of snow and drifting. If we had some sort of weather information system it would have to be able to pin point specific areas and then it would have to prove itself before we would stop going out every time to see for ourselves."

> "Some maintenance sheds do not have computers, all of this technology is a great help but we can only use it if we are at home."

"With the advent of the RWIS sites and NorthWest Weathernet, it has made decision making easier. More accurate information, gives us time to respond in a more proactive way to each situation. This brings about a greater reduction in wasted movements and equipment time."

"Most winter maintenance decisions should be made by crews on the road and in my area at least they are. I think that major decisions should involve the crews and sometimes that doesn't happen. Major decisions that include new equipment, new product distribution, types of equipment used should be run by people that use them."

"We still find that common sense, road patrols and experience are the most reliable current methods. We have several different weather patterns within our area no one piece of equipment could possibly give as valid and current a report as actually being out there."

SECTION 5: RWEATHER CUSTOMER SURVEY

Visitors to the rWeather website were invited to respond to a short on-line survey from March 6, 2001 to April 9, 2001. During that time 140 members of the public filled out the survey. In addition, 12 WSDOT personnel also responded to the survey. The objectives of this survey were to better understand who used the site, what kinds of trips they were planning with information they derived from the site, the features of the site they used and how useful they found these features to be for their trip planning, and suggestions they might have for enhancing the overall value of the site. A replica of the survey that was placed on-line is shown in Appendix B.

In interpreting findings from this survey, it is important to point out that respondents were self-selected; that is, the results of this survey reflect the opinions of only individuals who decided on their own to respond. Since the sample of respondents was not scientifically selected, their opinions do not necessarily reflect the opinions of all rWeather site users or of the general population of highway users in the Northwest. Nevertheless, these respondents reflect a diverse and interested group of private and commercial users of road-weather information available on the Internet, and their opinions can be very helpful in better understanding the types of road-weather information that are most useful, how that information is being used, and how websites like rWeather can potentially be improved so that they can better serve the general traveling public.

ANALYSIS OF SURVEY RESULTS

While somewhat over half (54.4%) of the respondents were frequent users of the rWeather website (more than three times a month), one-third of the respondents said they were visiting for the first time when they answered the survey questions. For many of the survey questions, it will be useful to focus on the responses of the more experienced users

of the site, so this analysis will look at differences between the comments of the first time and the more frequent site users (see Figure 5-1).

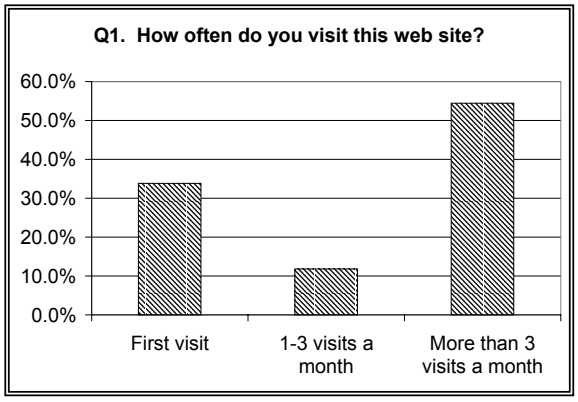


Figure 5-1: Frequency of Use

The second question on the survey asked respondents to indicate how frequently they used the site for various reasons. Figure 5-2 excludes the first time users, and shows the percentage of experienced site users who said they used the site "sometimes," "frequently" or "always" for five different reasons. Ninety percent of the respondents indicated that they frequently or always used the site to help them prepare for driving conditions along their route, and 86 percent said they frequently or always used the site to find out about weather conditions in general. Two-thirds used it to check weather conditions for a specific recreational activity, and fewer still primarily used the site for trip timing or route selection purposes. Use of the site for trip timing and route selection occurred mainly on an occasional basis, though some always use the site for these purposes. However, as indicated in Figure 5-2, a significant portion of frequent site users said they frequently or always used the site for one or another of these reasons; thus, it seems fair to conclude that the site offers a variety of different high value benefits for different users.

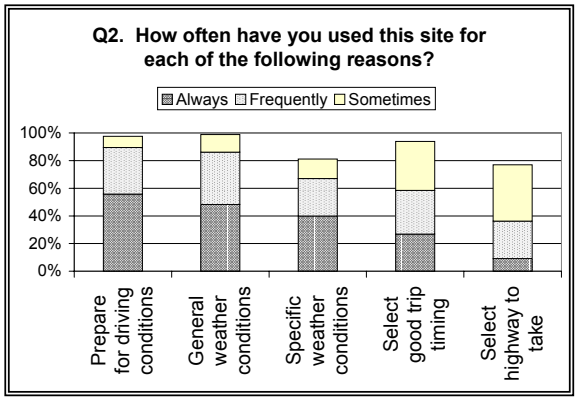


Figure 5-2: Frequency and Reason for Use

While deciding which highway to take was the least frequently cited reason for visiting the website over all, respondents from Central Washington and outside Washington state were somewhat more likely to select this option (frequently or always) than respondents from Western or Eastern Washington (45.2 percent versus 32.4 percent). However, there were very few site visitors from outside Washington (10 visitors or 7.2 percent of the 140 visitors), so it is difficult to draw conclusions about this group because of the small number of respondents. The visitors from Central Washington and outside Washington State also were somewhat more likely to cite preparing for driving conditions along their route. Western and Central Washington site users were more likely than users from other locations to indicate frequent use of the site to check for weather conditions for a specific recreational activity.

Use of the rWeather site has increased significantly over the past year. Figure 5-3 shows the average number of user sessions per day between March 2000 and December 2001. This chart also shows the variability in usage of the site in each month in terms of the range from the heaviest day of use to the lightest day of use in that month.[18] The winter months experienced the highest levels of use as well as the most extremes of usage

[18] The daily number of user sessions was not available to estimate the range of use for the months of March 2000 to June 2000. Daily ranges for the other months were estimated based on monthly graphics generated by WSDOT and made available on their website.

on a day-to-day basis. In February 2001, for example, a daily average of 3,741 user sessions was recorded for the site, but on February 16th, usage exploded to almost 13,000 user sessions that day, about three and a half times the average for the month. In fact February 16, 2001, was the Friday before the three-day President's Day holiday, and furthermore those days experienced particularly bad winter weather in the passes and other parts of the state.

As a general matter, use of the rWeather site is growing over time, though another year of usage data is needed to sort out longer term growth trends from the seasonal factors that impact use levels. For the ten consecutive months of March through December, overall use of the website increased 86 percent from 2000 to 2001, nearly doubling the number of rWeather users. Growth in site use is also implied by the fact that new users seem to be visiting the website in significant numbers, as about one-third of the respondents to the web survey were first time visitors to the site.

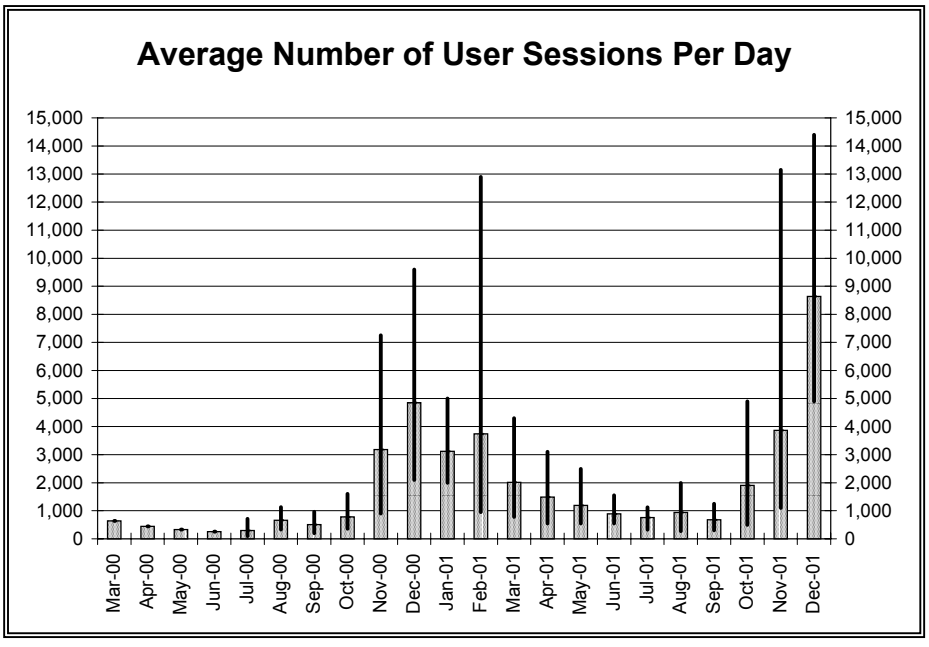


Figure 5-3: User Sessions Per Day

As shown by the data in Figure 5-4, the site is used most frequently to plan recreational and other personal trips of more than 100 miles. About half of the respondents to the survey indicated that this was their main use of the site, and younger respondents to the survey were more likely to indicate the use of the site for recreational trips than older respondents. The site is also more frequently used to plan for longer rather than shorter business trips. Those who use the site to plan for trips of 100 miles or less were fairly equally distributed over commuting trips, recreational trips, and other personal trips (between 18.6 percent and 24.3 percent of users plan these types of trips frequently).

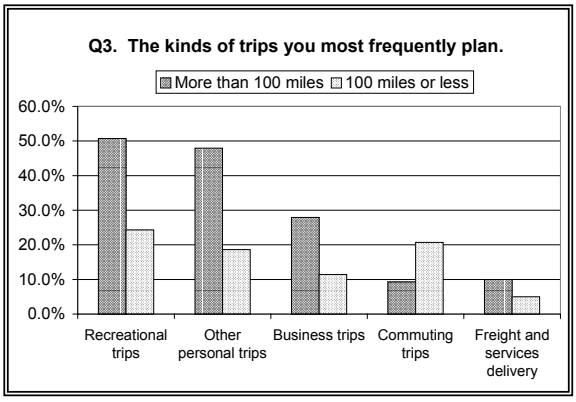


Figure 5-4: Kinds of Trips

Visitors to the website were asked to rate 13 different features of the site. For those features that they actually used, they rated the level of usefulness, and for those they didn't use, they indicated whether they were aware that each feature was available to them on the site. Figure 5-5 shows the overall level of usage reported for these features. The frequently used features include weather and pass conditions, traffic cameras, and road temperatures. Less frequently used features include construction activities, traffic incidents, audio highway advisories, and marine weather information. However, even for the less frequently used features, at least half of the respondents reported using them.

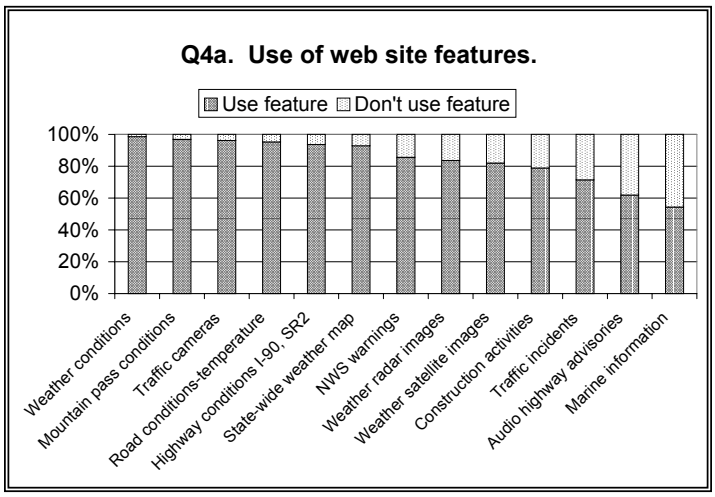


Figure 5-5: Use of Website Features

As can be seen in Figure 5-5, most of the respondents reported themselves as users of most of the features of the site. Those who didn't use a particular feature were typically about evenly split between those who said they were aware of the feature but don't use it and those who say they are not aware of the feature. The detailed data on this split can be seen for Question 4 in Appendix B. There were higher portions of the first time users among those who reported that they were not aware of a particular feature. Presumably, their level of awareness of what is available on this website would grow as they gain more experience over successive visits to the site.

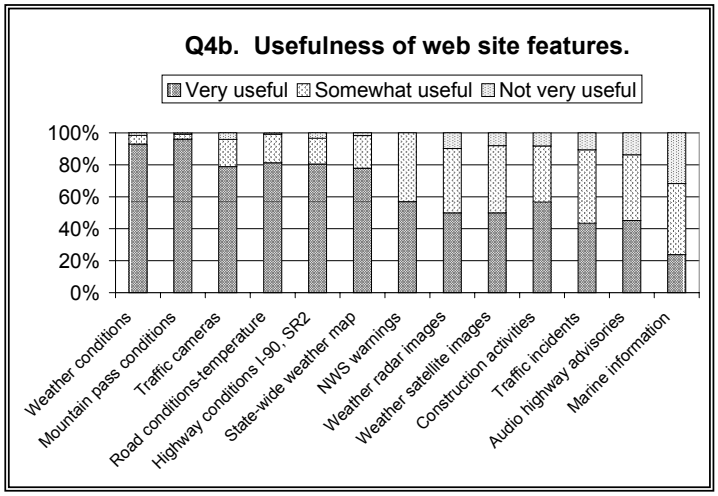


Figure 5-6: Usefulness of Website Features

Figure 5-6 shows the reported usefulness of various site features for those who reported using each feature. Weather conditions and mountain pass conditions were judged to be the two most useful features. Traffic cameras, road temperatures, highway conditions and the state-wide weather map were evaluated as very useful by about eighty percent of those who said they used these features of the website. Note that at least half of all the users of these features said that each feature was very or somewhat useful. Given the self-selected nature of this sample, however, respondents who may have used particular features and stopped using the site because they didn't find them useful would not be represented here. That is, users of each feature were likely to be those individuals who found a measure of usefulness in it or at least continued to visit the website because it was useful to them. Nevertheless, the range of evaluations of usefulness offers a picture of which features are the more highly valued by the user community.

Respondents were asked to evaluate the site in terms of their level of agreement or disagreement with various attributes. Figure 5-7 shows the proportion of respondents who said they "strongly agree" or "somewhat agree" with each attribute, arranged in terms of declining overall support for the statements, which are shown in their full wording in Appendix B. About 90 percent or more of these site visitors agreed that the site is well organized, that the site helps them be better prepared for road and weather conditions when they travel, that their use of the site makes their trips safer, and that they feel confident about the accuracy of the information about both current and forecast conditions. In terms of strength of agreement, the site is most valued for its ability to prepare travelers for road and weather conditions. Users also felt more confident (stronger agreement) in the accuracy of reported current conditions than forecast conditions.

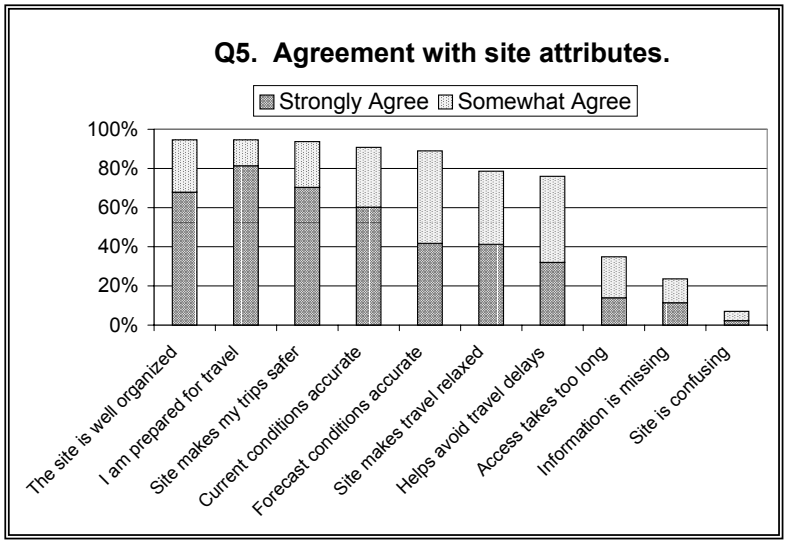


Figure 5-7: Agreement with Site Attributes

Slightly over one-third of the users agreed that it took them too long to access some of the information on the site, and about one-quarter of them said that important information was missing from the site that should be made available. Responses to the open-ended comments offered some additional discussion and suggestions regarding these concerns. Only 7 percent of respondents agreed that the site was confusing and difficult to use (81 percent disagreed with this statement). Overall, this is a very positive reaction to these important aspects of the rWeather website.

The perceived usability of the rWeather site is an important issue for WSDOT, and four of the attributes of the website examined bear on how useable respondents find it. Figure 5-8 compares the opinions on site usability of first time users with those of frequent users. The figure compares the percentage of first time users and frequent users who said they "strongly agree" with each of these four usability indicators. While the differences between these two groups are not very large, each of the four comparisons supports the interpretation that first time users find the site somewhat more difficult to use than experienced users. First time users are less likely to strongly agree that the site is well organized, and more likely to agree that accessing information on the site takes

too long, that important information is missing from the site, and that the site is confusing and difficult to use.

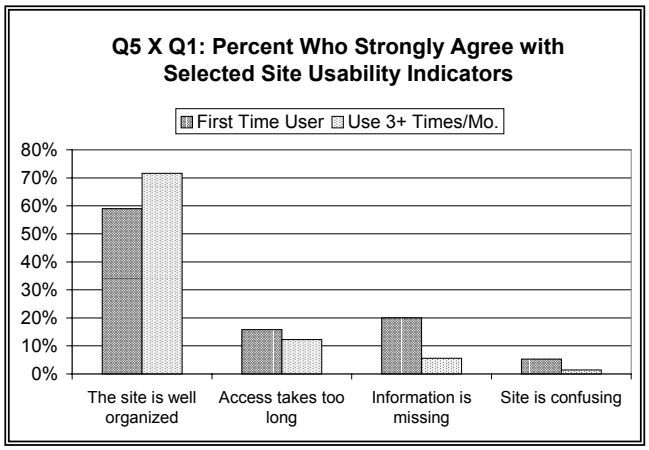


Figure 5-8: Usability Indicators

Obviously, as can be seen in the figure, very few respondents, regardless of experience with the site, said they strongly agree that the site is confusing and difficult to use. For this question, it is helpful to look at the percentage who strongly disagree. Fifty-eight percent of the first time users said they strongly disagreed that the site was confusing, but 75 percent of the experienced users strongly disagreed. So while many first time users clearly find the site perfectly usable, some do not, and more of these were in this first timer group than in the experienced group of users.

One explanation for this difference in the sample could be that the experienced users had figured out the site and continued to use it, whereas those who tried it and had difficulty very likely had given up and no longer use it. Those who had problems may have stopped using the site and thus would not be in the self-selected sample. Another explanation can be inferred from the users who were not sure about this question. Four times as many first time users as experienced users (21.1 percent versus 5.6 percent) said that they are neutral on the question of site difficulty (i.e., neither agreed nor disagreed), which suggests that they hade not had time to make up their minds and wanted more experience with the site to make a judgment.

COMMENTS PROVIDED BY USERS

Just over half of the respondents (71 or 50.7 percent) offered comments when asked to suggest how the website could be improved to better meet their needs. Suggestions tended to cluster around several common topics, including a desire for more camera images, more current information, broader and more consistent geographic coverage, and some site design concerns that mostly centered on the way frames were being used to present information. Many of the problems that some users experienced seemed to be related to the use of Macintosh computers and the Netscape browser, causing loading delays and problems with graphic images.[19] Some respondents related some interesting, and somewhat unusual, uses of the rWeather site, and many others simply wanted to offer their gratitude for a site they found very useful. These comments are summarized below.

Suggestions

- Would like more cameras, especially in Central Washington locations.
- More frequent updating of mountain pass pictures (camera images), especially for skiers.
- Would like a camera image of coastal weather, such as at the parking lot at Rialto Beach.
- More cameras around the Olympia area. Also links to other states' cameras to facilitate long distance travel.
- It would be nice if the cameras could be more protected from the weather for clearer pictures and if site temperatures could be shown in the frame.
- Need a camera on Mt. Baker highway.
- E-mail alerts for pass closures or snow warnings.
- Bring up the left buttons first for selections so we don't have to wait for the entire page to load when we know what we're looking for.
- There's too much stuff on this site so suggest splitting the information across two different sites, with cameras, temperatures and pass conditions on one and the "remaining garbage" on another.
- I am a professional truck driver and I would find it very useful to have current conditions reported in the areas of I-82 from Ellensburg to Yakima, an area of road more treacherous than most of our mountain passes. For in and out of state truckers, more road information would be greatly appreciated.

[19] The rWeather website was not specifically developed and tested for use in a Macintosh environment.

- Please bring back all the POS sites, especially for Cowiche, Ahtanum, Nachees and Pamona.
- It would be helpful to include Oregon and Idaho on the site.
- Need more up-to-date and detailed information on closures and accidents.
- Need more coverage, such as SR-20, North Cascades Highway, Chinook and White Passes, I-82 and Yakima canyon.
- Need more cameras and information covering I-82 and other parts of Central and Eastern Washington, including Yakima and the Tri Cities.
- Need more current information – two to four hour old information has little value to travelers.
- Information should be updated on site if possible as soon as it is submitted from various sources.
- Need more national satellite image information.
- The rWeather site should be made easier to track down from the WSDOT website.
- A longer forecast period of five days would be beneficial but I understand it would be less accurate.
- Get rid of the Netscape 6.0 warning!
- I would like to see the satellite loop so I can make my own forecast guesses.
- Ideally I would like to be able to enter my starting point and destination and get a road condition report for that route.
- I would like to see a weather station in the Mountain Loop area.
- "Just make the map bigger."
- When you click on a weather station it would be helpful if it indicated its location.
- It would help to be able to expand the size of a frame to make the text easier to read.
- Need a better design, perhaps eliminating or reducing the number of frames.
- The frames are fixed (in Netscape at least) and too small to hold all the information available, so it would be useful if the frames could be resized using the mouse so that I could look at the information of most interest to me in more detail.
- I would rather have a frameless page that uses client side scripting for fitting more interactive information into a small area.

Problems Experienced

- Takes too long to download; you get an error message if you try to use site before it is completely downloaded.
- The site takes too long to load and the links were not working (at least I was not willing to wait to see if they were).
- On my iMac with Netscape 4+ I get an error message if I try to access a camera image before a prior camera view has completely downloaded.
- Needs to load faster on dial-up connections.
- Images sometimes don't load on Linux.
- The map in the center section wouldn't load completely on my Mac—it would stall or hang.

- On my Mac, after viewing and closing the highway display showing temperature and road conditions, when I then click on either the I-90 or US-2 icons, nothing happens, so I have to completely close and reopen the site to view those icons.
- I am using Netscape 6 and I can't get any of the information I want off this site today.
- The site is too complicated and takes too long. The old site was better and easier to navigate. I rate the site now a 5 on a 1-10 scale.
- The site is very slow to load on my iMAC, but graphics work well.
- The Diamond Point site often has very high winds but I was unable to bring up the current wind speed in real time nor could I find what the wind speeds had been recently.
- Information is not shown equally (or completely) at all of the weather stations on the site.
- The site lacks road conditions for Central and South Eastern Washington State.
- I have problems with this site from time to time using my Netscape 6.0.

Creative Uses of Site

- I work in the hotel industry, and I use this site to provide highway and pass condition information to hotel guests.
- We have a recreational home and check the site frequently to see what is happening there.
- We are a concrete manufacturer in Walla Walla and use the map to inform contractors of weather conditions and to check highways to make sure they are safe for our heavy rock trucks.
- I travel frequently between Bothell and Vantage and always check this site first for weather and I-90 conditions.
- Our law firm has posted this site to all of us via e-mail. Almost all of the site information is pertinent to my business travel.
- My wife used to live in Ephrata and now we live in California. I notify her from my desk in Southern California about Washington pass conditions when she travels home in the winter based on information I get from your website.

Positive quotes (with minor paraphrasing)

- "Your site is well organized, useful and easy to use."
- "The real time camera images are a very important feature for me."
- "I checked other weather sites that had issued avalanche warnings so I checked your site which pointed out that these warnings were for the back country and not our driving route. My kids and I were happy and reassured. Thank you! I have bookmarked this site for future trips."
- "The site makes excellent use of graphics and colors to indicate road and weather conditions."
- "Please do not change the site layout. It is good the way it is and very easy to get around. Keep up the good work."
- "I feel the site is great as it is presented."
- "I like the icing tutorial."

- "I enjoy using this site every day. Very useful and informative. Thanks."
- "I find this site to be tremendously helpful. I can't think of any other information that is needed."
- "This site is the best. Thanks. Good job."
- "I find this to be a worthwhile service."
- "I am a construction superintendent and I drive every week from Yakima to Bothell and back. I find the site easy to use and can't think how it could be improved."
- "Keep up the good work and don't stop providing us with all your good info. We use your site about 3 to 4 times a day. Thank you."
- "The website is terrific!"
- "No complaints. Excellent site. One of the best sites that I have seen."
- "This is my first visit to the site but I can assure you I'll be back. Keep it up!"
- "Everything I need to know is on this site."
- "This site seems much improved over the prior system of regional DOT sites. The construction and traffic delay information are extremely helpful. My congratulations on a great site."
- "Overall, this is one of the very most useful sites I've ever found. Great job!"

SUMMARY

In the month that the survey was posted on the rWeather website, 140 users of the site responded, offering their opinions and suggestions. Overall, use of the site has been growing over the past year, perhaps by a factor of three during this period, though more time and data are needed to distinguish long-term growth trends from the wide seasonal variation in use experienced at this site. About one-third of the respondents were first-time users and over half were frequent users. They were overwhelmingly positive in their assessment of the value of the site in helping them prepare for their travel and learn about weather and road conditions. Use of this site is different from many other traveler information sites in that users are predominantly focused on longer trips. More than twice as many users said they were most frequently planning recreational, business, and other personal trips of over 100 miles in comparison to those using the website to plan shorter trips.

Virtually all of the site's informational features were used by most visitors and their ratings of the usefulness of these features were high for all the main features,

including weather conditions, mountain pass conditions, traffic cameras, road temperatures, and state-wide maps. About half the respondents offered specific suggestions that tended to cluster around several common topics, including a desire for more camera images, more current information, broader and more consistent geographic coverage, and some site design modifications. A few Mac and Netscape users reported problems. The great majority of users who responded to the survey said they found the site well organized and generally easy to use, with information that is easy to fine Some concerns were reported regarding site usability, and evidence suggests that first-time users had more difficulties than experienced users. Overall, however, the response to this website was very positive. Comments such as, "The website is terrific," and "One of the best sites that I have seen," capture the opinion of many of the survey respondents.

SECTION 6: FINDINGS AND RECOMMENDATIONS

Major strides have been made recently in WSDOT's implementation of RWIS as a result of the rWeather program. The most significant of these are equipment compatibility; development of a statewide RWIS network, including an extensive set of non-WSDOT weather sensors; access to statewide comprehensive weather information, weather training; and a public information website.

However, WSDOT maintenance personnel are not taking full advantage of the state's RWIS investment. At the same time, it is clear that enthusiasm for implementing advanced snow and ice control practices is growing, and maintenance personnel have expressed extensive support for additional RWIS stations and weather interpretation training.

BARRIERS TO FULL USE

The barriers to full use of RWIS capabilities can be grouped under the following headings:

- Lack of experience
- Lack of confidence
- Lack of access
- Lack of training
- Resistance to change
- Liability concerns
- RWIS equipment and rWeather website issues
- Limitations of existing technology

Findings and recommendations associated with each of these barriers are presented below.

Lack of Experience

Findings

The learning curve itself is a barrier to the implementation of advanced winter maintenance practices. It is difficult to take full advantage of technologies for which there has been little experience, as is the case for RWIS in most of Washington. As with any change in tools and procedures, expectations become more realistic with use.

To some extent the lack of confidence in weather forecasts, RWIS sensor stations, and the performance of anti-icing chemicals are all directly related to a lack of experience with these data sources and materials. The results of the maintenance personnel survey clearly indicate that those with the most experience with RWIS capabilities and proactive maintenance practices are the most optimistic about the potential of these technologies and strategies. These employees also use more sophisticated sources of weather information, and they are the most interested in improvements to weather forecasts that will help them more effectively and efficiently implement advanced snow and ice control practices. It is also clear that adequate training and access encourage use of more sophisticated sources of weather information such as SCAN Web, rWeather, other Internet websites and commercial forecast services.

Those without experience relying on weather forecasts view them as insufficient for good maintenance decision-making, with more than half of the survey respondents citing the need to continue routine patrols despite improvements in weather forecasting. As noted by Boselly (1993), "DOTs tend to base their assessment of the utility of forecasting services on perception and intuition rather than generating even simple statistics such as percentage of correct forecasts."

Recommendations

The push to use more advanced (and expensive), proactive snow and ice control strategies will force the use of RWIS as a means to control the cost of these strategies. Already, experience with RWIS and anti-icing in the North Central Region is reducing

the barriers to implementation in the other regions. Weather data archiving and monitoring of snow and ice control performance will become increasingly important as a way to learn from experience. The winter maintenance plan developed for the North Central Region includes a mechanism to document snow and ice control performance for each storm or storm segment, and it recommends a post-storm analysis as part of a total storm management strategy (Boselly, 2000a).

Lack of confidence

Findings

For the purposes of implementing proactive winter maintenance practices, reliable and tailored forecasts of weather and pavement temperature are essential. A lack of confidence in these forecasts is a major barrier to using them to support changes in snow and ice control practices. WSDOT maintenance personnel express very little confidence in weather forecasts and virtually no confidence in pavement temperature forecasts. There is even concern about the reliability of RWIS station weather observations.

Outside of the North Central Region, which contracts for tailored weather forecasts, winter maintenance personnel rely on the same high-level forecasts that are provided to the general public by the National Weather Service. These forecasts cannot provide the level of detail necessary to implement advanced snow and ice control practices, and they do not address pavement temperatures at all. In addition, as with most information sources, people are far more likely to remember poor forecasts than good ones.

Less than half of the maintenance personnel who reported having used rWeather viewed the pavement temperatures and forecasts as useful. This appears to be partly due to a lack of knowledge about the importance of pavement temperature forecasts and partly due to a lack of confidence in these forecasts, especially at the detail level that is useful for maintenance decision-making. It is important to note that thanks to increases in

computing power and additional detection technology, tremendous advances are being made in the ability to forecast weather.

Maintenance personnel have a great interest in weather forecasts with improved reliability and more detail, and most respondents in the survey thought they would increase their use of anti-icing strategies if they had better weather information.

Recommendations

It is important to be able to demonstrate to maintenance personnel the reliability of the rWeather pavement temperatures and forecasts being generated by computer models at the University of Washington. Comparisons between forecast and actual pavement temperatures and atmospheric weather conditions need to be made and shared with maintenance personnel.

The reliability of tailored, vendor-provided weather forecasts needs to be determined by keeping records of forecast and actual conditions. A simple framework useful for summarizing weather forecast performance is shown in Figure 6-1. This framework was developed as a tool for evaluating the FORTELL project, a multi-state weather information field operational test. (Battelle 1998).

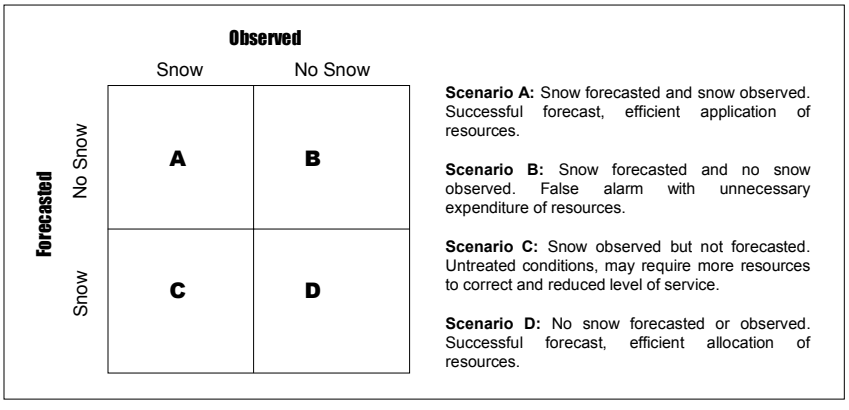


Figure 6-1: FORTELL Weather Forecast Evaluation Model

WSDOT's contracts for forecasting services should be performance based. Several state DOTs have started to require stated levels of reliability from contractors providing tailored weather forecasts. For example, Wisconsin DOT (WisDOT) decided that maintenance personnel had to have a forecast product that they had confidence in and could rely on if Wisconsin was going to forge ahead with plans to use anti-icing techniques and if it was going to continue intensive efforts to reduce salt use while still maintaining a high level of service. In 1997 WisDOT awarded its first contract for new forecast services to a vendor that was required to meet WisDOT's service and reliability requirements.

The new contract contains language requiring the forecast agency to notify Wisconsin counties 4 hours before snowfalls of more than 1 inch or freezing rain events are forecast to start and 2 hours before other snowfall events are expected. It also requires the forecast agency to immediately notify the county when the forecast changes during storm events. The new forecast services contract includes similar specific language for pavement temperature forecasts.

WisDOT has undertaken an effort to verify the weather and pavement temperature forecasts using common meteorological techniques to determine the accuracy of the vendor's forecasts, including timing error, percentage of correct determination for snow, freezing rain, and air and pavement temperatures dropping below freezing. The forecast verification rate is expected to be 85 percent or better. An average forecast verification rate of less than 85 percent is grounds for the customer to cancel the contract (Adams 1998).

Lack of Access

Findings

Access to RWIS information is essential in order for that information to be used to support advanced winter maintenance practices. The findings of the maintenance

personnel survey indicate that a large percentage of maintenance sheds and lead techs do not have access to the Internet, the primary method of accessing RWIS and other weather information.

Somewhat surprisingly, the level of comfort in using the Internet is very high (87 percent are very or moderately comfortable), indicating that an investment in Internet access would be worthwhile.

Recommendations

Provide computers and Internet access in all maintenance sheds and ensure that computers with Internet access are available to all personnel tasked with making winter maintenance decisions.

Lack of Training

Findings

The survey of maintenance personnel clearly shows a need for, and an interest in, training in several areas. The survey also indicates that personnel who have received more training are more open to the use of RWIS and advanced snow and ice control practices. Specific findings include the following:

- Personnel are interested in additional training in interpreting weather information in general. Lead techs are less likely than supervisors to have had this type of training. This is a problem if, as often is the case, lead techs are tasked with making snow and ice control decisions.
- Adequate knowledge about how weather and pavement temperature influence road surface condition is lacking. Many of the survey respondents underestimated the value of pavement temperature in snow and ice control decision-making.

- Personnel also have a high degree of interest in learning more about modern snow and ice control practices, especially anti-icing strategies, in order to take advantage of them.
- Maintenance personnel indicate that they are satisfied with RWIS training they have received, but the survey indicates that most lead techs and supervisors have not had any RWIS training, clearly an impediment to its use.
- SCAN Web is not being used extensively. In the Eastern Region this reflected a lack of access to SCAN Web during the period of the survey. In other regions this may indicate a need for training, or it may indicate a lack of confidence in RWIS weather observations.

Recommendations

Provide training, particularly in the interpretation of weather information and the application of anti-icing strategies. Make an effort to focus the right training on the right people.

Multiple Internet resources are available and heavily used by maintenance personnel for weather information. It would be advantageous to train maintenance personnel in the potential pitfalls of these sources and the best ways to take advantage of them.

Resistance to Change

Findings

Winter maintenance crews have a high degree of pride in the work that they perform, and RWIS isn't necessary to continue the reactive approaches to snow and ice control. However, significant changes in business practices are required to achieve the operating cost savings promised by RWIS. Specifically, routine road patrols need to be eliminated and staffing strategies need to be revised.

The elimination of routine road patrols is probably the most problematic. Patrols are heavily relied upon as a source of weather and road condition observations, and they are an integral part of how business is done. In fact, many believe that even with improved weather information, patrols would be necessary.

As mentioned earlier, areas in the North Central Region have already made changes in crew staffing that have resulted in the elimination of routine night and weekend shifts, a change reportedly well received by the employees.

Another aspect of resistance to change is the desire to avoid risk. In the case of anti-icing, the cost of applying anti-icing chemicals where they are not needed is very high. In addition, some maintenance personnel are not sure of the safety of anti-icing chemicals, which if applied incorrectly can actually make the road slippery.

Even some members of the public are resistant to change, as evidenced by the petition against anti-icing submitted by residents of the Methow Valley.

Recommendations

A statewide transition to more cost-effective winter maintenance practices will require a strong management stance on the need to make change and a commitment to training. In addition, WSDOT should continue its efforts to educate the public about the potential safety, cost, and environmental benefits of using anti-icing chemicals.

Liability Concerns

Findings

There are two concerns related to liability. The first is a concern that the use of anti-icing chemicals will generate vehicle damage claims. The second concern is that not using anti-icing will generate accident-related lawsuits claiming negligence on the part of WSDOT.

According to the Risk Management Office[20], WSDOT has been "steadfast" in denying claims of damage related to anti-icing chemicals and sand, citing that the DOT's duty to provide safe roads overrides the duty to protect individual property. In the case of damage from sand, claims are rarely paid and if they are, the payments are small. However, liability has been an issue in cases in which improperly applied anti-icing chemicals have led to slippery conditions.

The demonstrated capabilities of RWIS could constitute the state-of-the-art in snow and ice control technology. Such a view could make highway agencies liable if they did not acquire and properly use the technology. However, information from a representative in the Washington State Attorney General's Office (who is also a longtime member of the Transportation Research Board's Tort Liability and Risk Management Committee)[21] indicates that, although snow and ice is a significant area of liability for WSDOT, charges of negligence for not using RWIS and advanced maintenance practices have not become an issue for Washington. Furthermore, they have not been an issue for any other state DOT, most of which are not required to mitigate the consequences of weather the way that Washington is. However, he cautioned that tort liability related to the use of RWIS capabilities and anti-icing strategies may very well become an issue if part of the state adopts improved methods and others do not. A lack of consistent implementation of advanced winter maintenance practices and uniform compliance with associated procedures could definitely weaken the state's ability to defend itself against claims.

If WSDOT adopts more sophisticated approaches and a new standard of care, travelers can be expected to raise their level of service expectations. A change to the use of advanced winter maintenance practices needs to have a well planned and documented,

[20] Phone conversation, Bill Henselman, WSDOT Risk Management, February 12, 2001.
21 Phone conversation, Mike Tardif, State Attorney General's Office, February 12, 2001.

staged implementation. Anti-icing efforts to date have been characterized as experimental.

Recommendations

Development of a well-documented implementation plan is essential to address liability concerns related to non-experimental use of RWIS and advanced winter maintenance practices.

RWIS Equipment and rWeather Website Issues

Findings

The maintenance personnel survey results indicated that between 70 and 75 percent of the respondents were somewhat or not at all satisfied with the accuracy, reliability, or location of the RWIS sensor stations in their area.

The rWeather website has proven itself as a valuable tool for travelers (especially for long distanced trips), and as it has evolved it has continued to address traveler information needs. According to the maintenance personnel survey, 50 percent of those surveyed use the rWeather website. For maintenance staff this is the only resource that provides access to the network of non-WSDOT weather station information and the only place to find pavement temperatures and forecasts.

One issue no doubt responsible for the relatively low level of use is the lack of Internet access by many of the survey respondents. In addition, however, maintenance personnel have expressed dissatisfaction with the lack of detail available on the site. The RWIS sensor station reports lack some important detail that is available on SCAN Web, and the pavement temperatures are too general to support winter maintenance decision-making. These design decisions were made out of concern for minimizing WSDOT's liability for information provided to the public. As a result of trying to address both audiences, the rWeather website has become a better tool for travelers than for maintenance staff.

As of late 2001 the rWeather website has become the corner stone of integrated traveler information on the WSDOT website, taking advantage of rWeather's success in providing road and weather information to travelers.

Recommendations

The rWeather program has upgraded many RWIS station sites over the last couple of years, and many concerns about sensor reliability may have been addressed by now. However, a full review of the accuracy and reliability of all RWIS sensor station equipment would ensure that the equipment is able to adequately support improvements in winter maintenance practices. Funding for ongoing maintenance of these stations is also necessary. Consideration should also be given to ongoing funding of centralized RWIS technical support.

WSDOT should consider adding RWIS detail and pavement temperature detail components to the site formerly known as rWeather, accessible only to WSDOT personnel through the WSDOT Intranet as a way of heightening the sites usefulness for winter maintenance decision making. Looking to the future, a WSDOT-only portion of the website could also be used for tracking where and when anti-icing chemicals have been applied, currently a critical missing piece in the electronic information available for snow and ice control.

Limitations of Existing Technology

Findings

The following list highlights some limitations to existing technologies that are currently barriers to more extensive use of RWIS:

- Chemical presence and concentration detectors are notoriously unreliable. This information is key to efficient anti-icing strategies.
- Some of the most difficult to predict conditions are frost and black ice because of limitations in the ability to forecast humidity. Statewide, these

road conditions are the most common and they respond well to anti-icing strategies.

- Currently, weather forecasting technologies make it is easier to produce reliable forecasts in some parts of the state than in others. This is due in part to the radar and satellite resources available and in part to the propensity for weather conditions to change more rapidly in some areas than in others. Effective placement of additional RWIS stations provides information critical to improving the ability to forecast conditions in these difficult areas.

Recommendations

The potential value of RWIS varies from region to region as a result of the type of weather and road conditions that need to be addressed and the ability to reliably forecast conditions. Only with reliable forecasts can advanced winter maintenance practices be efficiently implemented. Additional RWIS resources need to be focused on areas where the potential to change snow and ice control practices exists and where additional sensor capability will contribute to improved weather forecasting.

All of these technology limitations are being addressed and will be resolved over time.

SUMMARY OF RECOMMENDATIONS

Many of the recommendations identified above, and summarized below, are already being addressed through continued investments in RWIS sensor stations, Internet access, and additional weather-related training. In addition, current plans call for hiring a meteorologist to address the need for analysis of statewide forecast reliability and equipment performance.

1. Continue to share information about experiences with RWIS and advanced winter maintenance practices as a way to reduce barriers to expanded use.
2. Document and review snow and ice control methods and results throughout the winter season.
3. Document the reliability of rWeather pavement temperature forecasts and share the results with winter maintenance personnel.
4. Require weather forecast service to meet defined performance criteria.
5. Provide computers and Internet access in all maintenance sheds and ensure that computers with Internet access are available to all personnel tasked with making winter maintenance decisions.
6. Provide training, particularly in the interpretation of weather information and the application of anti-icing strategies. Make an effort to focus the right training on the right people.
7. Train maintenance personnel in the potential pitfalls of the multitude of Internet sources of weather information and the best ways to take advantage of them.
8. Provide strong management support for the need to make change and demonstrate a commitment to necessary training.
9. Continue efforts to educate the public about the potential safety, cost, and environmental benefits of using anti-icing chemicals.
10. Develop a well-documented plan for statewide, uniform implementation of advanced winter maintenance practices to address liability concerns.
11. Make a full review of the accuracy and reliability of all RWIS sensor station equipment.
12. Ensure funding for ongoing maintenance of RWIS sensor stations.
13. Consider ongoing funding of centralized RWIS technical support.

14. Focus additional RWIS resources on areas where the potential to change snow and ice control practices exists and where additional sensor capability will contribute to improved weather forecasting.

SECTION 7: CONCLUSION

RWIS enables cost effective, proactive winter maintenance practices that improve the level of service provided and lead tech to increased safety and mobility for the traveling public. Although proactive maintenance practices such as anti-icing can be implemented without a comprehensive RWIS, such implementations are very costly because use of labor, equipment, and materials is often beyond what is necessary.

In Washington, the rWeather program has significantly improved the RWIS resources available for winter maintenance decision-making. The rWeather program has also resulted in development of a weather and road condition website highly valued by long-distance travelers.

This research has shown that WSDOT maintenance personnel have not taken full advantage of the capabilities of RWIS, in part because these capabilities are not necessary to continue traditional, reactive winter maintenance strategies. Expanding the use of RWIS and advanced winter maintenance practices will require management commitment and continued investment in equipment reliability, demonstration of forecast credibility, targeted training, and implementation planning.

SECTION 8: REFERENCES

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APPENDIX A: ROAD WEATHER INFORMATION QUESTIONNAIRE

This questionnaire is part of a study of the road weather information resources available to maintenance staff within the Washington State Department of Transportation. The answers you provide will help guide further WSDOT investments in road weather information. Please return the completed questionnaire by ***May 1st, 2001*** to:

Catherine Boon
Washington State Transportation Center
1107 NE 45th Street, Suite 535
Seattle, WA 98105-4631

Name: _____

Date: _____

Position: __Supervisory staff (57), Lead techs (72)_____

Section(shed): __Eastern Region (26), North Central Region (24), Northwest Region (26), Olympic Region (24), South Central Region (23), Southwest Region (6)_____

1. Please indicate your ***first*** most common winter maintenance issue:
   - ☐ Frost **(63)**
   - ☐ Black ice **(33)**
   - ☐ Freezing fog **(5)**
   - ☐ Snow accumulation **(23)**
   - ☐ Blowing or drifting snow **(0)**
   - ☐ Other_____

2. Please indicate your ***second*** most common winter maintenance issue:
   - ☐ Frost **(21)**
   - ☐ Black ice **(46)**
   - ☐ Freezing fog **(17)**
   - ☐ Snow accumulation **(41)**
   - ☐ Blowing or drifting snow **(3)**
   - ☐ Other_____

3. Please indicate the extent to which you used each of the following snow and ice control practices during the 2000/2001 winter season:

	Used Extensively	Used Moderately	Used Minimally	Not Used At All
Patrols	**(68)**	**(39)**	**(18)**	**(3)**
Plowing and sanding	**(43)**	**(56)**	**(29)**	**(0)**
Anti-icing (chemicals to *prevent* ice/road bond)	**(33)**	**(61)**	**(25)**	**(7)**
Deicing (chemicals to *break* ice/road bond)	**(14)**	**(25)**	**(43)**	**(40)**

4. Please indicate how often you consulted the following sources of weather information to make winter maintenance decisions during the winter of 2000/2001:

	Daily	Weekly	Monthly	Annually	Never
SCAN Web - only for your RWIS* stations	**(22)**	**(10)**	**(3)**	**(1)**	**(79)**
SCAN Web - for RWIS stations outside your section	**(11)**	**(15)**	**(9)**	**(2)**	**(73)**
WSDOT's rWeather website	**(34)**	**(31)**	**(6)**	**(2)**	**(41)**
National Weather Service website	**(30)**	**(37)**	**(8)**	**(2)**	**(34)**
Weather Channel website	**(24)**	**(22)**	**(9)**	**(1)**	**(56)**
Other Internet website	**(27)**	**(23)**	**(10)**	**(3)**	**(42)**
Forecasting service such as Northwest Weather Net	**(52)**	**(10)**	**(3)**	**(1)**	**(47)**
Local broadcast radio	**(92)**	**(10)**	**(3)**	**(2)**	**(12)**
NOAA radio	**(18)**	**(14)**	**(7)**	**(2)**	**(68)**
Local broadcast TV	**(95)**	**(11)**	**(0)**	**(0)**	**(15)**
Cable TV weather station	**(46)**	**(13)**	**(3)**	**(3)**	**(45)**
Road patrol reports within your section	**(103)**	**(7)**	**(1)**	**(0)**	**(6)**
Road patrol reports from areas outside your section	**(36)**	**(23)**	**(6)**	**(3)**	**(36)**
Other: _____**DTN**___	**(4)**				

*RWIS - Road Weather Information System

5. During the winter of 2000/2001, how satisfied were you with the weather information you had available for making winter maintenance decisions?
   - ☐ Very satisfied **(13)**
   - ☐ Generally satisfied **(70)**
   - ☐ Somewhat satisfied **(27)**
   - ☐ Marginally satisfied **(14)**
   - ☐ Not at all satisfied **(3)**

6. Have you experienced any of the following as a result of the use of detailed weather information?
   - ☐ More efficient use of labor **(68)**
   - ☐ Fewer labor hours **(42)**
   - ☐ Reduced equipment usage **(43)**
   - ☐ Lower material cost (sand, chemicals) **(43)**

7. Which of the following improvements to your weather information, if any, would be valuable to you: (select all that apply)
   - ☐ Improved reliability **(78)**
   - ☐ More frequent updates **(40)**
   - ☐ Better tailored to road maintenance issues **(53)**
   - ☐ More detailed and targeted to specific areas **(78)**
   - ☐ Other, please explain

     _____

8. Do you think that improvements in the weather information you have available to you would encourage you to *increase* your use of anti-icing strategies?
   - ☐ Yes **(89)**
   - ☐ No **(33)**

9. Do you think that improvements in the weather information you have available to you would encourage you to *reduce* your use of patrols?
   - ☐ Yes **(51)**
   - ☐ No **(69)**

10. For the following weather services, please rate each one in terms of ease of use, availability (works when you need it), usefulness for making maintenance decisions, and your level of confidence in the information. Circle your rating as High, Med (medium) or Low.

	Don't Use	Ease of Use	Availability	Usefulness	Confidence
SCAN Web	**(70)**	**High (19) Med (20) Low (7)**	**High (21) Med (19) Low (6)**	**High (16) Med (23) Low (6)**	**High (8) Med (31) Low (6)**
WSDOT's rWeather website	**(49)**	**High (34) Med (28) Low (9)**	**High (39) Med (20) Low (11)**	**High (20) Med (38) Low (11)**	**High (10) Med (42) Low (14)**
Weather forecasting service*	**(39)**	**High (54) Med (24) Low (4)**	**High (52) Med (21) Low (5)**	**High (32) Med (40) Low (3)**	**High (7) Med (52) Low (14)**

*NorthWest Weathernet for example.

11. How useful to you is each of the following site-specific information for making snow and ice control decisions?

	Very Useful	Somewhat Useful	Not Useful
Air temperature	**(108)**	**(16)**	**(1)**
Changes in air temperature over last 24 hours	**(42)**	**(65)**	**(12)**
Wind speed and direction	**(43)**	**(67)**	**(13)**
Pavement temperature	**(93)**	**(26)**	**(6)**
Changes in pavement temperature over last 24 hours	**(44)**	**(54)**	**(20)**
Dew point, relative humidity	**(54)**	**(53)**	**(13)**
Road surface condition (dry, wet, ice)	**(109)**	**(14)**	**(1)**
Road subsurface temperature	**(44)**	**(56)**	**(20)**
Precipitation/snowfall	**(103)**	**(17)**	**(5)**
Chemical presence	**(55)**	**(46)**	**(19)**
Chemical concentration	**(49)**	**(48)**	**(23)**
Visibility	**(49)**	**(57)**	**(14)**
Camera images on the web	**(39)**	**(48)**	**(33)**

12. Is the training you have received in interpreting weather information adequate for you to make snow and ice control decisions?
   - ☐ Yes **(43)**
   - ☐ No **(15)**
   - ☐ I have not received training to interpret weather information **(68)**

13. Do you personally have access to the Internet at work?
    - ☐ Yes **(105)**
    - ☐ No (please skip to question 16) **(22)**

14. What kind of connection do you have to the Internet at work?
    - ☐ Regular 28.8 or 56K dial up modem **(35)**
    - ☐ High speed DSL or Cable modem **(7)**
    - ☐ T1 line **(32)**
    - ☐ Wireless network **(0)**
    - ☐ I have a connection but I'm not sure what kind it is **(26)**
    - ☐ Other _____

15. In your workplace, is Internet access limited because of security and abuse concerns?
    - ☐ Yes **(65)**
    - ☐ No **(43)**

16. How comfortable are you getting information from each of the following sources?

	Have Never Used	Very Comfortable	Moderately Comfortable	Marginally Comfortable	Not at all Comfortable
Internet	**(18)**	**(53)**	**(41)**	**(14)**	**(1)**
Internal WSDOT network (Intranet)	**(19)**	**(63)**	**(34)**	**(8)**	**(1)**
Electronic Mail	**(18)**	**(85)**	**(15)**	**(3)**	**(4)**
Pager (text messages)	**(69)**	**(26)**	**(12)**	**(5)**	**(8)**
Voice Mail (telephone answering machine)	**(39)**	**(43)**	**(22)**	**(9)**	**(9)**
FAX	**(19)**	**(65)**	**(28)**	**(8)**	**(5)**
TV/Radio	**(5)**	**(79)**	**(27)**	**(13)**	**(2)**

17. Do you have any RWIS sensor station in your maintenance section?
    - ☐ Yes, **(42)** How many? _____
    - ☐ No (please skip to question 20) **(82)**

18. Please indicate the capabilities your RWIS stations had available (working) during most of this winter (2000/2001) season:

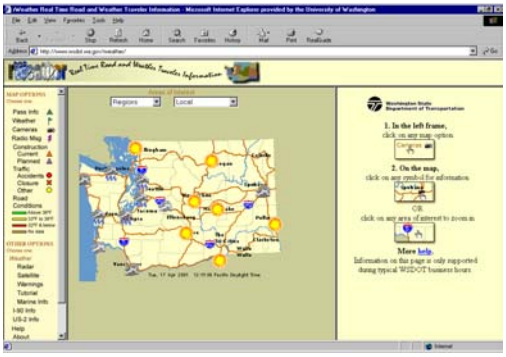
	All stations had this	Some stations had this	No stations had this	Don't Know
Air temperature	**(32)**	**(0)**	**(1)**	**(8)**
Pavement temperature	**(29)**	**(0)**	**(3)**	**(7)**
Sub-surface temperature	**(20)**	**(2)**	**(6)**	**(10)**
Visibility	**(10)**	**(3)**	**(12)**	**(9)**
Chemical presence	**(14)**	**(1)**	**(10)**	**(11)**
Chemical concentration	**(11)**	**(0)**	**(13)**	**(12)**
Precipitation	**(28)**	**(1)**	**(2)**	**(9)**
Wind speed and direction	**(30)**	**(2)**	**(1)**	**(8)**

19. Please indicate your satisfaction with the following aspects of your RWIS stations:

	Very Satisfied	Somewhat Satisfied	Not at all Satisfied
Equipment reliability	**(10)**	**(26)**	**(6)**
Data accuracy	**(12)**	**(24)**	**(6)**
Location of existing stations	**(12)**	**(21)**	**(10)**
Availability of training	**(4)**	**(22)**	**(15)**

20. Would additional RWIS stations in your maintenance section be useful to you in making snow and ice control decisions?
    - ☐ Yes **(87)**
    - ☐ No **(16)**

21. Are you aware of WSDOT's rWeather Internet website? (See sample screen at right.)
    - ☐ Yes **(99)**
    - ☐ No (please skip to question 24) **(26)**



22. Have you ever used WSDOT's rWeather Internet website?
    - ☐ Yes **(77)**
    - ☐ No (please skip to question 24) **(27)**

23. Please rate each of the rWeather site's features in terms of its usefulness for maintenance decision making:

	Very Useful	Somewhat Useful	Not Useful	Haven't Used this Feature
Statewide weather map (shown above)	**(19)**	**(54)**	**(5)**	**(4)**
RWIS station weather conditions	**(28)**	**(26)**	**(10)**	**(14)**
Other weather station conditions	**(22)**	**(41)**	**(8)**	**(9)**
Camera images	**(22)**	**(43)**	**(6)**	**(9)**
Highway radio advisories	**(20)**	**(35)**	**(13)**	**(13)**
Construction activities	**(10)**	**(34)**	**(21)**	**(13)**
Current statewide pavement temperatures	**(10)**	**(27)**	**(24)**	**(19)**
Current and forecast pavement temperatures for I-90 and SR2	**(10)**	**(24)**	**(24)**	**(22)**
Weather radar images	**(39)**	**(32)**	**(5)**	**(4)**
Weather satellite images	**(37)**	**(35)**	**(5)**	**(3)**
National Weather Service warnings	**(37)**	**(37)**	**(1)**	**(6)**
Marine information (Ferry Weather)	**(7)**	**(9)**	**(31)**	**(32)**

24. In which of the following would you like to see WSDOT invest additional resources?

- ☐ RWIS station maintenance and operation (keep them working) **(58)**
- ☐ Training related to interpreting weather data **(86)**
- ☐ Training related to anti-icing strategies **(63)**
- ☐ Additional office computers **(28)**
- ☐ Improved Internet access **(29)**
- ☐ Thermal mapping (mapping of typical temperature variations along a section of roadway to support pavement temperature forecast models) **(37)**
- ☐ Statewide coordination of RWIS resources and weather-related strategies **(35)**
- ☐ Additional anti-icing equipment and storage facilities **(52)**
- ☐ Additional cameras at key locations **(47)**
- ☐ Additional RWIS stations **(65)**
- ☐ Additional weather and road condition information to the public **(55)**
- ☐ Other ____
  - **People to do the job**
  - **Intranet and Internet access and computers in each shed**
  - **Additional personnel**
  - **Actually use the electronic sign to advise the public**
  - **FTE's in maintenance to conduct snow and ice control.**
  - **Training on computers.**
  - **Automated anti-ice systems tied to RWIS**
  - **More chemicals that are less corrosive, coordination of RWIS resources and weather-related strategies by adjoining areas.**
  - **Home access for supervisors to the network and intranet**
  - **Better, non-corrosive chemicals**
  - **Improve and simplify weather and road info to public**

25. Please share any comments you have about the weather information and winter maintenance decision making:

- **Our outlying maintenance facilities have either no computers or very limited access. An improvement in this area would be very beneficial.**
- **At least one person on shift able to use Internet**
- **Any improvement is good. But enough people to do the job is the hardest of all.**
- **Some maintenance sheds do not have computers, all of this technology is a great help but we can only use it if we are at home.**
- **Our weather reports have a terrible time getting to the media or the road/pass conditions hotline. I maintain Sherman Pass and our updates are either too late or never make it at all to the media/public sites. (Internet -- WSDOT intranet or Pass Report Hotline)**
- **It seems that simple temperatures and camera images would be very helpful to maintenance.**
- **More weather information to the public when ice and snow are on the highways and inform them not to pass our trucks during snow and ice removal.**
- **Whidbey Island has several weather patterns and convergent zones. Our manpower is the same as what it was in 1940. Traffic volumes during AM & PM commute limit our ability to provide winter maintenance. Because limited personnel we either staff for a storm or routine maintenance we can't do both. If the storm doesn't come we don't get**

much done if it does we are maxed out. Most often we wait till it starts to snow then we are behind to start out.

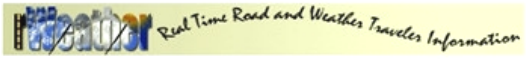
- **Anti-icing is expensive. Would need a very reliable source of weather information to offset increased costs. 15 years of experience is my training. Our winter maintenance planning is a result of a limited budget and the primary factor in our success is a dedicated, experienced crew. We usually don't have time to consult a forecast that originates in Seattle and has no corresponding impact on our local area. Recent attempts by our own agency to hamper our efforts are not appreciated. Vegetation planted in such a manner as to cause shading and lower road temperatures is a poor way to maintain a safe system.**
- **It is difficult using any weather information for decision making or planning due to rapid weather changes in this region.**
- **Due to the topography of our area going from 7ft above sea level to 1500 ft, it is almost impossible to predict weather. So it is necessary and will remain necessary to have a night shift for winter ice and snow patrol. I have areas where consistently the weather changes within 1/2 mile of a given geographical obstruction or change in elevation. Investing in expensive weather stations where solar and electrical supply is inconsistent is a waste of money. General prediction for large geographical areas given by WeatherNet, NOAA or National Weather Service only partially help predict what to expect.**
- **Need to have some comfort in the accuracy, I would need some demonstrated reliability of weather information (to increase anti-icing or reduce patrols), Don't have any RWIS stations in my area. Locations I'd be interested in them there is no power or telephone services. Past weather forecasting has been completely unreliable. Also the value gained didn't support the cost of the service. Long-range forecasts are rarely accurate. Two to three day forecasts may be 50/50. 24-hour forecasts are usually somewhat reliable.**
- **We still find that common sense, road patrols and experience are the most reliable current methods. We have several different weather patterns within our area no one piece of equipment could possibly give as valid and current a report as actually being out there.**
- **We need more info for specific site within your own area.**
- **It is pretty tough to count on weather info for more than a general idea. It is my opinion that without patrols we are not being prudent and responsible.**
- **Not all sites have cameras; maybe add some more in trouble spots.**
- **The rWeather site is great. Please add loops for IR satellite, radar and visible satellite.**
- **RWIS site would be very useful in my area due to the different landscape and temp change in other location.**
- **We could use another RWIS site on I-90 Dotson Interchange to help two sections.**
- **The best way to get advance warning is a person. By the time calls are made we have problems on the hills before we can respond.**
- **RWIS stations are a needed tool for WSDOT to maintain winter highways.**
- **This was not a good year to make these judgments, as it was so mild. During one snowstorm I was away on vacation. In my area there are several weather conditions present. This is difficult to do as an average.**
- **Liquids are the future in de and anti-icing. The equipment element of our future "business plan" must include innovation and shift to use of liquids, both for application of traction-enhancing abrasives and for anti-icing.**
- **RWIS are just aids. Nothing will replace visual observation of roadway conditions and experience and knowledge the maintenance crews have of their own individual areas.**
- **These sites are very helpful in making decisions in regard to snow and ice control.**
- **RWIS stations will be very helpful in the future as we get more stations to help maintenance areas make better decisions on how to address snow and ice conditions.**

- **Common sense, and curb the use of de-ice when temperatures are borderline. More than once last winter the stuff refroze and caused more problems. All that was accomplished is the problem was passed from one shift to another.**
- **Other than the radio or TV this weather station does not help us (maintenance people who do not have access). If we had access it would or could be very useful.**
- **Good. Need more information on de-icing.**
- **The RWIS sites in our area haven't worked for a number of years. Weather information isn't current. Usually 1-2 hours old. Most of our employees don't have access to the Internet.**
- **I was satisfied with the state weather reports and updates.**
- **It seemed that the information from the RWIS stations located within this region did not have up to date or current information when visiting the sites. Everything was hours an sometimes days old. It made it hard to make educated decisions based on old information.**
- **Our RWIS sites are not active at this time for our access but I think they could be an asset if they have real time reported.**
- **Although RWIS sites do have their benefits, I'm sure the expense to maintain these sites are substantial. This doesn't seem to be the time to spend dollars in large amounts for RWIS. I'm in favor of having a few RWIS sites but not so many as to trying to micromanage the weather systems. I understand efficiency is what we're striving for concerning weather conditions. Remember the snow plow operator is still our most reliable source of information.**
- **Internet access only as of April 30. Fast changing temps, ground fog, icing and traffic flows determine how fast or where roads ice in certain areas. These conditions change by the minute and are generally hard to predict. Roadway sensors would be nice in places but would only be partial info due to so many areas.**
- **Weather information -- possibly fewer call outs on next shift.**
- **Have a more reliable or better source of weather service for making good decisions. This would improve our labor, equipment and materials costs and also the safety for our customers.**
- **Bottom line maintenance has very little input.**
- **We are getting our RWIS station on White Pass updated to the new version. It was one of the first ones to come out and never really worked from the start.**
- **We still have no computers or access to anything except our home TV or radio and vehicle AM/FM radios.**
- **At Pullman we just go out over the sections if there is any question of frost or worse. After taking care of the same sections for 23 winters you begin to see a pattern in areas that are hardest hit so you just naturally check them. For instance, in Pullman you might have clear skies but south of downtown it could be 6" of snow and drifting. If we had some sort of weather information system it would have to be able to pin point specific areas and then it would have to prove itself before we would stop going out every time to see for ourselves.**
- **We have never had good weather data to make decisions with. We have used and contracted several different weather data providers with results about 50% accurate. In our business that is not accurate enough to make decisions with.**
- **Seems like most of the forecasts from any source are not accurate. We look at several and if there is a prediction then we may look for it sooner but usually it is wait and see what happens. Do our maintenance work then check our roads or vise versa depending on the shift. Anti-icing is done for frost control. De-icing is done during or after an event.**
- **I am very interested in RWIS and anti-ice technologies and have been a proponent of including these stations in future constructions. It seems odd that there are no RWIS stations on I-5 in the Olympic Region**
- **In my 17 years of experience, the Internet is probably the most useful in winter maintenance decisions. Accuracy and constant updates are essential in coordinating**

attack plans. Camera location and the thermal mapping in known problem areas would greatly enhance the level of service we need to provide the public.

- **Anti-icer % and presence is very important. Accuracy has to be improved.**
- **Biggest problem I have is not enough information on different roads -- contingency schedule needs better weather forecast information. More training on different products and when to use which ones for road conditions or forecast.**
- **Most winter maintenance decisions should be made by crews on the road and in my area at least they are. I think that major decisions should involve the crews and sometimes that doesn't happen. Major decisions that include new equipment, new product distribution, types of equipment used should be run by people that use them.**
- **With the advent of the RWIS sites and NW Weathernet, it has made decision making easier. More accurate information, gives us time to respond in a more proactive way to each situation. This brings about a greater reduction in wasted movements and equipment time.**
- **It would help in this shed to let crew leaders have access to Internet websites.**
- **I personally do not have access to a computer at work but occasionally access these sites on my home computer. We have access through our shop supervisor and he prints the forecasts out for us daily so we all are able to see them that way. Last year I felt they weren't real accurate at times but other times they were pretty close in prediction coming weather patterns.**
- **I would like some training on using the websites and the information given such as radar and satellite images. I attended one class on RWIS SCAN web and the class was far too large and dealt with how RWIS came to be and where it was going rather than here it is, this is how you use it now.**
- **The Northwest Avalanche Center is very good at forecasting. I do not have computer access at work. I access the Internet weather data through my computer at home.**
- **I see a lot of complaints from the public regarding WSDOT's web page not being kept current due to not providing after normal work hours staffing to keep it up to date with current information.**
- **It is easy to get information when on duty, after hours it can be sometimes difficult and time consuming.**
- **No matter how accurate weather forecast is it is impossible to make a deicing or anti-icing decision in this area based on forecast alone. Weather is an odd thing here and it usually takes a body to physically check out areas of concern. We have some drastic elevation changes, lakes, hills, etc. - all of this affects weather when it gets down near freezing/snowing temps.**
- **Use RWIS sites daily -- probably would use more weather sites off Internet (radar, satellite, etc.) but haven't taken time to find and learn to use them.)**
- **We do not find the rWeather site useful for maintenance decisions. We need more training for all the people who are going to be using this information. The training needs to be focused on using and interpreting the RWIS information specifically for maintenance purposes. i.e. what conditions will bring out frost.**
- **We need more training in snow and ice control and more extensive training in determining weather conditions.**
- **I think the direction we are going is good.**

APPENDIX B: RWEATHER CUSTOMER SURVEY



Online Questionnaire

Thank you for your interest in rating the features of the rWeather Web site. The Washington State Department of Transportation wants to provide you with timely and reliable information to help you travel safely. Your responses to this questionnaire will help us serve you better. This survey should take about 5 minutes to complete. Please respond only once to this questionnaire.

1. How often do you visit this web site?

   - ○ This is my first visit
   - ○ I visit the site one to three times a month
   - ○ I visit the site more than three times a month

2. How often have you used this site for each of the following reasons? (Please make a selection for each reason)

		Never	Sometimes	Frequently	Always
a.	To decide which highway to take	○	○	○	○
b.	To make sure it is a good time to make my trip	○	○	○	○
c.	To prepare myself for driving conditions along my route	○	○	○	○
d.	To check weather conditions for a specific recreational activity	○	○	○	○
e.	To find out about weather conditions in general	○	○	○	○
f.	Other:	○	○	○	○

3. Considering all the times you have used this site, indicate the kinds of trips you *most frequently* plan: (Check all that apply)

		Trips of 100 miles or less	Trips of more than 100 miles
a.	Commuting for school or work	☐	☐
b.	Business trips	☐	☐
c.	Recreational trips	☐	☐
d.	Other personal trips	☐	☐
e.	Freight hauling or goods/services delivery	☐	☐

4. Now we would like you to rate the usefulness of each of the features of this web site that you have *used* at least once. For each feature that you have *not* used, please indicate whether you were aware of this feature before taking this survey. (Please make a selection for each feature.)

		Use Feature			**Don't Use Feature**	
		Very Useful	Somewhat Useful	Not Very Useful	Aware of it	Not Aware of it
a.	State-wide weather map	○	○	○	○	○
b.	Mountain pass conditions	○	○	○	○	○
c.	Weather conditions	○	○	○	○	○
d.	Traffic cameras	○	○	○	○	○
e.	Audio highway advisories	○	○	○	○	○
f.	Construction activities	○	○	○	○	○
g.	Traffic incidents	○	○	○	○	○
h.	Road conditions (temperature)	○	○	○	○	○
i.	Weather radar images	○	○	○	○	○
j.	Weather satellite images	○	○	○	○	○
k.	National Weather Service warnings	○	○	○	○	○
l.	Marine information (Ferry Weather)	○	○	○	○	○
m.	Current and forecast highway conditions (I-90, SR2)	○	○	○	○	○

5. Based on your experience using this site, please evaluate the site in terms of the following aspects. Indicate your level of agreement with each of these statements:

		Strongly Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Strongly Disagree
a.	The site is well organized.	○	○	○	○	○
b.	I am confident about the accuracy of the information about *current* conditions.	○	○	○	○	○
c.	I am confident about the accuracy of the information about *forecast* conditions.	○	○	○	○	○
d.	My use of this site makes my trips safer.	○	○	○	○	○
e.	It takes me too long to access some of the information on this site.	○	○	○	○	○
f.	There is important information missing from this site that should be made available here.	○	○	○	○	○
g.	The information I get from this site helps me avoid travel delays.	○	○	○	○	○
h.	This site helps me to be better prepared for road and weather conditions when I travel.	○	○	○	○	○
i.	I find this site confusing and difficult to use.	○	○	○	○	○
j.	The information I get from this site makes me more relaxed on my trips.	○	○	○	○	○

6. Please also indicate, in your own words, how this web site could be improved to better meet your needs. Consider information content, ease of use of the site, ability to understand what is presented, and anything else that could make this site better. Be as specific as you can:

7. Please indicate the region in which you live.

   ○ Western Washington
   ○ Central Washington
   ○ Eastern Washington
   ○ Outside of Washington state

8. Please check your age category.

   ○ 16 years or younger
   ○ 17 to 24
   ○ 25 to 34
   ○ 35 to 44
   ○ 45 to 54
   ○ 55 to 64
   ○ 65 years or older

Submit

RWeather Customer Survey Results

1. How often do you visit this website?

	Frequency	Percent
This is my first visit	46	33.8%
I visit the site one to three times a month	16	11.8%
I visit the site more than three times a month	74	54.4%
Totals:[22]	136	100.0%

2. How often have you used this site for each of the following reasons?

   a. To decide which highway to take.

	Frequency	Percent
Never	27	25.7%
Sometimes	40	38.1%
Frequently	29	27.6%
Always	9	8.6%
Totals:	105	100.0%

   b. To make sure it is a good time to make my trip.

	Frequency	Percent
Never	13	11.8%
Sometimes	37	33.6%
Frequently	34	30.9%
Always	26	23.6%
Totals:	110	100.0%

   c. To prepare myself for driving conditions along my route.

	Frequency	Percent
Never	7	6.0%
Sometimes	15	12.9%
Frequently	34	29.3%
Always	60	51.7%
Totals:	116	100.0%

[22] Total responses for each question in the survey reflect only the number of individuals who actually answered the question. Since some respondents skipped one or more questions, the total number of responses for each question is typically somewhat less than 140.

d. To check weather conditions for a specific recreational activity.

	Frequency	Percent
Never	27	23.7%
Sometimes	17	14.9%
Frequently	31	27.2%
Always	39	34.2%
Totals:	114	100.0%

e. To find out about weather conditions in general.

	Frequency	Percent
Never	7	5.9%
Sometimes	19	16.1%
Frequently	43	36.4%
Always	49	41.5%
Totals:	118	100.0%

3. Considering all the times you have used this site, indicate the kinds of trips you *most frequently* plan.

a. Commuting for school or work.

	Frequency	Percent
Trips of 100 miles or less	29	20.7%
Trips of more than 100 miles	13	9.3%

b. Business trips

	Frequency	Percent
Trips of 100 miles or less	16	11.4%
Trips of more than 100 miles	39	27.9%

c. Recreational trips

	Frequency	Percent
Trips of 100 miles or less	34	24.3%
Trips of more than 100 miles	71	50.7%

d. Other personal trips.

	Frequency	Percent
Trips of 100 miles or less	26	18.6%
Trips of more than 100 miles	67	47.9%

e. Freight hauling or goods/services delivery

	Frequency	Percent
Trips of 100 miles or less	7	5.0%
Trips of more than 100 miles	14	10.0%

4. Rate the usefulness of each of the features of this website that you have *used* at least once. For each feature that you have *not* used, please indicate whether you were aware of this feature before taking this survey.

a. State-wide weather map

	Frequency	Percent
Use this feature	117	92.9%
Very useful	91	72.2%
Somewhat useful	24	19.0%
Not very useful	2	1.6%
Don't use this feature	9	7.1%
Aware of it	4	3.2%
Not aware of it	5	4.0%
Totals:	126	100.0%

b. Mountain pass conditions

	Frequency	Percent
Use this feature	127	96.9%
Very useful	122	93.1%
Somewhat useful	4	3.1%
Not very useful	1	0.8%
Don't use this feature	4	3.1%
Aware of it	3	2.3%
Not aware of it	1	0.8%
Totals:	131	100.0%

c. Weather conditions

	Frequency	Percent
Use this feature	129	98.5%
Very useful	120	91.6%
Somewhat useful	7	5.3%
Not very useful	2	1.5%
Don't use this feature	2	1.5%
Aware of it	0	0.0%
Not aware of it	2	1.5%
Totals:	131	100.0%

d. Traffic cameras

	Frequency	Percent
Use this feature	123	96.1%
Very useful	97	75.8%
Somewhat useful	21	16.4%
Not very useful	5	3.9%
Don't use this feature	5	3.9%
Aware of it	2	1.6%
Not aware of it	3	2.3%
Totals:	128	100.0%

e. Audio highway advisories

	Frequency	Percent
Use this feature	73	61.9%
Very useful	33	28.0%
Somewhat useful	30	25.4%
Not very useful	10	8.5%
Don't use this feature	45	38.1%
Aware of it	18	15.3%
Not aware of it	27	22.9%
Totals:	118	100.0%

f. Construction activities

	Frequency	Percent
Use this feature	97	78.9%
Very useful	55	44.7%
Somewhat useful	34	27.6%
Not very useful	8	6.5%
Don't use this feature	26	21.1%
Aware of it	14	11.4%
Not aware of it	12	9.8%
Totals:	123	100.0%

g. Traffic incidents

	Frequency	Percent
Use this feature	85	71.4%
Very useful	37	31.1%
Somewhat useful	39	32.8%
Not very useful	9	7.6%
Don't use this feature	34	28.6%
Aware of it	18	15.1%
Not aware of it	16	13.4%
Totals:	119	100.0%

h. Road conditions (temperature)

	Frequency	Percent
Use this feature	123	95.3%
Very useful	100	77.5%
Somewhat useful	22	17.1%
Not very useful	1	0.8%
Don't use this feature	6	4.7%
Aware of it	4	3.1%
Not aware of it	2	1.6%
Totals:	129	100.0%

i. Weather radar images

	Frequency	Percent
Use this feature	102	83.6%
Very useful	51	41.8%
Somewhat useful	41	33.6%
Not very useful	10	8.2%
Don't use this feature	20	16.4%
Aware of it	10	8.2%
Not aware of it	10	8.2%
Totals:	122	100.0%

j. Weather satellite images

	Frequency	Percent
Use this feature	100	82.0%
Very useful	50	41.0%
Somewhat useful	42	34.4%
Not very useful	8	6.6%
Don't use this feature	22	18.0%
Aware of it	10	8.2%
Not aware of it	12	9.8%
Totals:	122	100.0%

k. National Weather Service warnings

	Frequency	Percent
Use this feature	107	85.6%
Very useful	61	48.8%
Somewhat useful	46	36.8%
Not very useful	0	0.0%
Don't use this feature	18	14.4%
Aware of it	4	3.2%
Not aware of it	14	11.2%
Totals:	125	100.0%

l. Marine information (Ferry Weather)

	Frequency	Percent
Use this feature	63	54.3%
Very useful	15	12.9%
Somewhat useful	28	24.1%
Not very useful	20	17.2%
Don't use this feature	53	45.7%
Aware of it	33	28.4%
Not aware of it	20	17.2%
Totals:	116	100.0%

m. Current and forecast highway conditions (I-90, SR2)

	Frequency	Percent
Use this feature	118	93.7%
Very useful	95	75.4%
Somewhat useful	19	15.1%
Not very useful	4	3.2%
Don't use this feature	8	6.3%
Aware of it	5	4.0%
Not aware of it	3	2.4%
Totals:	126	100.0%

5. Based on your experience using this site, please evaluate the site in terms of the following aspects. Indicate your level of agreement with each of these statements.

a. The site is well organized.

	Frequency	Percent
Strongly agree	89	67.9%
Somewhat agree	35	26.7%
Neither agree nor disagree	3	2.3%
Somewhat disagree	4	3.1%
Strongly disagree	0	0.0%
Totals:	131	100.0%

b. I am confident about the accuracy of the information about *current* conditions.

	Frequency	Percent
Strongly agree	77	60.2%
Somewhat agree	39	30.5%
Neither agree nor disagree	8	6.3%
Somewhat disagree	2	1.6%
Strongly disagree	2	1.6%
Totals:	128	100.0%

c. I am confident about the accuracy of the information about *forecast* conditions.

	Frequency	Percent
Strongly agree	53	41.7%
Somewhat agree	60	47.2%
Neither agree nor disagree	10	7.9%
Somewhat disagree	4	3.1%
Strongly disagree	0	0.0%
Totals:	127	100.0%

d. My use of this site makes my trips safer.

	Frequency	Percent
Strongly agree	90	70.3%
Somewhat agree	30	23.4%
Neither agree nor disagree	7	5.5%
Somewhat disagree	1	0.8%
Strongly disagree	0	0.0%
Totals:	128	100.0%

e. It takes me too long to access some of the information on this site..

	Frequency	Percent
Strongly agree	18	14.0%
Somewhat agree	27	20.9%
Neither agree nor disagree	29	22.5%
Somewhat disagree	25	19.4%
Strongly disagree	30	23.3%
Totals:	129	100.0%

f. There is important information missing from this site that should be made available here.

	Frequency	Percent
Strongly agree	14	11.4%
Somewhat agree	15	12.2%
Neither agree nor disagree	44	35.8%
Somewhat disagree	25	20.3%
Strongly disagree	25	20.3%
Totals:	123	100.0%

g. The information I get from this site helps me avoid travel delays.

	Frequency	Percent
Strongly agree	40	32.0%
Somewhat agree	55	44.0%
Neither agree nor disagree	24	19.2%
Somewhat disagree	6	4.8%
Strongly disagree	0	0.0%
Totals:	125	100.0%

h. This site helps me to be better prepared for road and weather conditions when I travel.

	Frequency	Percent
Strongly agree	105	81.4%
Somewhat agree	17	13.2%
Neither agree nor disagree	6	4.7%
Somewhat disagree	0	0.0%
Strongly disagree	1	0.8%
Totals:	129	100.0%

i. I find this site confusing and difficult to use.

	Frequency	Percent
Strongly agree	3	2.3%
Somewhat agree	6	4.7%
Neither agree nor disagree	14	10.9%
Somewhat disagree	19	14.8%
Strongly disagree	86	67.2%
Totals:	128	100.0%

j. The information I get from this site makes me more relaxed on my trips.

	Frequency	Percent
Strongly agree	52	41.3%
Somewhat agree	47	37.3%
Neither agree nor disagree	25	19.8%
Somewhat disagree	2	1.6%
Strongly disagree	0	0.0%
Totals:	126	100.0%

6. Please also indicate, in your own words, how this website could be improved to better meet your needs. Consider information content, ease of use of the site, ability to understand what is presented, and anything else that could make this site better. Be as specific as you can.

Comments were provided by 72 out of 140 respondents (51.0%). See text for an overview analysis of these comments.

7. Please indicate the region in which you live.

	Frequency	Percent
Western Washington	77	55.8%
Central Washington	27	19.6%
Eastern Washington	24	17.4%
Outside of Washington state	10	7.2%
Totals:	138	100.0%

8. Please check your age category.

	Frequency	Percent
16 years of younger	0	0.0%
17 to 24	1	0.7%
25 to 34	14	10.2%
35 to 44	34	24.8%
45 to 54	45	32.8%
55 to 64	33	24.1%
65 years or older	10	7.3%
Totals:	137	100.0%