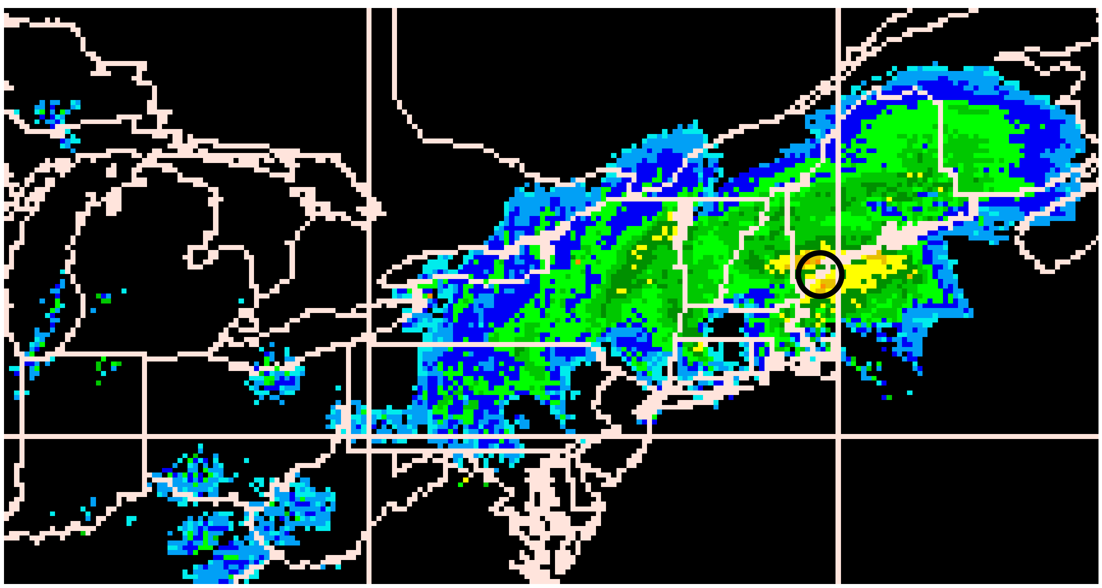
A Case Study of the Maintenance Decision Support System (MDSS) in Maine



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16. Abstract

This report presents the results of a case study evaluation of a Maintenance Decision Support System (MDSS) project under a program funded by the U.S. Department of Transportation's (USDOT) Intelligent Transportation Systems (ITS) Joint Program Office. The Federal Highway Administration (FHWA) Road Weather Management Program (RWMP) has sponsored development of a prototype Maintenance Decision Support System (MDSS). The federal MDSS prototype software modules are available to private vendors who have utilized them to develop decision support applications tailored to the needs of state Departments of Transportation (DOTs). An MDSS is being offered to the Scarborough crew of the Maine Department of Transportation (MaineDOT), by Meteorlogix/DTN. The DTN system, known as WeatherSentry, includes MDSS capabilities. Experience to date suggests that significant benefits are possible from the use of an MDSS, including improved productivity (e.g., reduced material costs, more efficient use of labor), enhanced mobility, and improved safety. The MDSS offers guidance for maintenance managers and engineers that provides forecasts of weather and pavement conditions and recommendations on efficient maintenance treatment strategies. The MDSS is a unique tool that provides an integrated GIS platform along with significant educational value to users. This research is being conducted to evaluate the concept of an MDSS by assessing the uses and benefits of MDSS deployment on a segment of interstate in the vicinity of Portland, ME, based upon a comparison of historical winter maintenance practices and those practices facilitated through the use of the MDSS tools. The objectives of this research are to assess institutional issues and potential benefits of using an MDSS, and to identify from MaineDOT's experience lessons of value to other DOTs across the country. The evaluation team worked with MaineDOT to identify these benefits and lessons from their use of the MDSS in support of winter maintenance operations during the winter of 2006-2007. This assessment examined the institutional challenges faced by MaineDOT's Scarborough crew and the strategies they employed as they used a variety of tools, including the MDSS, to fight each of the winter storm events they faced. Using a detailed event reconstruction approach, data were collected for 12 winter storm events that required a maintenance response in order to characterize the uses of the MDSS as a maintenance tool, versus not using an MDSS (i.e., how maintenance operations would have been conducted prior to having access to an MDSS). Lessons learned are derived from the reconstruction of these storm events that may be of use to other state DOTs considering implementing the MDSS technology.

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List of Acronyms

ASOS	Automated Surface Observing System
DOT	Department of Transportation
DTN	DTN/Meteorlogix, the MDSS vendor
ESS	Environmental Sensor Station
FHWA	Federal Highway Administration
GIS	Geographic Information System
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
LOS	Level of Service
MATS	Maintenance Activity Tracking System
MaineDOT	Maine Department of Transportation
MDSS	Maintenance Decision Support System
NHDOT	New Hampshire Department of Transportation
NWS	National Weather Service
PPLM	Pounds Per Lane Mile (chemical application rate)
RWIS	Road Weather Information System
SNTHERM	SNowTHERmalModel
USDOT	U.S. Department of Transportation

Executive Summary

Introduction. This report presents the results of a case study evaluation of a Maintenance Decision Support System (MDSS) project under a program funded by the U.S. Department of Transportation's (USDOT) Intelligent Transportation Systems (ITS) Joint Program Office. The Federal Highway Administration (FHWA) Road Weather Management Program (RWMP) has sponsored development of a prototype Maintenance Decision Support System (MDSS). The federal MDSS prototype software modules are available to private vendors who have utilized them to develop decision support applications tailored to the needs of state Departments of Transportation (DOTs). An MDSS was offered to the Scarborough crew of the Maine Department of Transportation (MaineDOT) by Meteorlogix/DTN for use during the winter of 2006-2007 in the region of Portland, ME. The DTN system, known as WeatherSentry, includes MDSS capabilities.

Methodology. The methodology used to assess the benefits and lessons learned associated with the use of an MDSS by the MaineDOT Scarborough crew involved a careful tracking of each of 12 winter storm events that occurred in the study region (a 12-mile segment of interstate in Portland, ME) during the winter of 2006-2007, coupled with reconstruction of the crew's decision processes and treatment actions throughout each event. MaineDOT records a daily statistical record of labor hours, materials and equipment usage and costs, plus the timing and nature of treatments applied during each storm event. The evaluation team tracked the observed weather conditions recorded for each storm at the Portland Jetport Automated Surface Observing System (ASOS) facility. Also, archived records of the MDSS hourly forecasts and treatment recommendations were tracked throughout the duration of each storm event. Finally, every alert issued by the MDSS, based on parameters selected by the Scarborough crew, were tracked.

A narrative was developed describing each event based on a telephone debriefing with members of the Scarborough crew and supervisor, coupled with an analysis of the available MDSS data and observational data from other sources. The debriefing discussion followed a structured set of questions that were designed to elicit what happened in each event, how the Scarborough crew responded to the event, what information was used to assist the crew in deciding how to respond to the event, and how information provided by the MDSS was accessed and used in the event. In summarizing the assessment of each reconstructed event, the intent was to determine and describe whether and how the MDSS was of benefit and the magnitude of that benefit through better timed and more efficient treatment actions and in terms of lessons learned from the response process that could be of value to other DOTs. A key element in these post-event discussions was to explore with the supervisor and crew how they thought they would have responded in the absence of the MDSS as a way to understand the role and benefit of the MDSS.

Findings and Lessons. Compared with typical winters in Maine, the winter of 2006-2007 was milder and there were fewer severe storm events. For each event, the Scarborough crew sought to include the MDSS in their decision making in ways they thought would be helpful. This first winter with the MDSS provided the crew with an opportunity to experiment with their uses of the MDSS. The experience overall was positive, though the available data were not adequate to support a more quantitative assessment of cost savings from the use of the MDSS. Nevertheless, MaineDOT personnel said they benefited from this first season with the MDSS in a number of more qualitative ways. The following are findings from this experience:

- **The MDSS offers valuable training and learning opportunities for the crew.** State DOT road maintenance supervisors and crews are highly experienced and skilled at their winter road maintenance jobs, but they generally lack experience with new computer-based support technologies and are often skeptical of the benefits such technologies offer. The Maine management and crews found this first season with the MDSS provided them with a valuable training experience. DOT managers saw this as a needed first step toward integrating route-specific weather and pavement condition information along with region-wide National Weather Service (NWS) forecasts on a Geographic Information System (GIS) platform. It offered the crews an opportunity to experiment with the new technology with the training and support of the MDSS vendor.
- **The full potential of MDSS is yet to be realized**. To gain the most benefit from an MDSS requires time to understand the various "pathways to benefits" by which an MDSS, through road weather forecasts and pavement treatment recommendations, can guide maintenance crews to more efficient and cost-effective operations. The learning and acceptance process takes time, and expectations need to be managed accordingly. MaineDOT views the MDSS as offering an effective training environment to help raise the bar for all their statewide crews.
- **An MDSS offers an important new tool in a maintenance toolbox.** Many of the core capabilities of an MDSS have not previously been available to DOTs. These include pavement temperature and bridge frost forecasts, ready access to historical trends, more precise location-specific weather forecasts, locally tuned pavement treatment recommendations, and helpful alerts to support more effective decision making. A key benefit to MaineDOT was the availability in the MDSS of an integrated platform for weather forecast display and analysis statewide. Thus, it supplemented not only their traditional maintenance support tools, such as other weather forecasting services or crew observations and experienced judgment, but also added new value and tied all this together into a well-integrated decision support system.
- **MDSS forecast accuracy and consistency help build trust.** An MDSS provides a tool intended to yield high quality, timely weather forecasts at a much more granular level than is typical of current DOT practice, including route-specific forecasts. If it can do this well and consistently, then it will fill a niche capability not offered by the more traditional regional weather forecast services. The circumstances encountered in Maine during the winter of 2006-2007 were particularly challenging because of maritime climate effects in the Portland area and temperatures close to freezing in most of the storm events. The MDSS was reasonably effective in forecasting storm timing but it was especially difficult to forecast precipitation type and amounts. An MDSS can benefit from the availability of good observational data along the corridors subject to forecasts as a way to fine tune those forecasts.
- **Treatment recommendations in an MDSS need to be fine-tuned to reflect unique local treatment practices and microclimates.** State DOTs need to work closely with the MDSS vendor to develop customized treatment recommendations that incorporate local conditions and crew practices as well as national and state best maintenance practices. In the case of MaineDOT, the statewide average treatment recommendations

that were incorporated into the MDSS were frequently seen as offering inadequate material amounts for the road conditions encountered in the Portland area. Since the MDSS treatment recommendations were infrequently followed, it was not possible to evaluate their efficacy during this evaluation period. This experience emphasizes the importance of configuring the MDSS with a treatment regime that is seen as appropriate by the local crews and that they are willing to implement consistently.

- **MDSS provides a new way of looking at treatment decisions.** By understanding the context and utility of previously unavailable information, such as road temperature trends and bridge frost forecasts, maintenance crews can improve their decision making on how best to treat their roads. For example, road temperature trends provided to MaineDOT by the MDSS were useful as crews planned their treatments. With the MDSS providing a wealth of data, training the supervisors and the crew in accessing and utilizing these new features provided by an MDSS is critical.
- **Communicating MDSS recommendations and forward correction are critical to optimal MDSS performance during storm events.** Crews need effective ways to access the MDSS recommendations during a storm event. Similarly, the MDSS needs to be updated with the latest field reports on road conditions and treatments performed. Maintenance supervisors and crews typically find themselves consumed with the tasks of "fighting the storm" and feel they have no time to stay connected with the MDSS. Under these conditions, they are more prone to rely on their experiences and judgment than to take the time to access and follow the MDSS recommendations.

Conclusions. The MDSS deployed by MaineDOT in the winter of 2006-2007 offered the DOT and the Scarborough road maintenance crew a useful winter storm planning tool. In its current configuration, it is primarily a weather forecasting tool. The needs of state DOT's vary widely, and many that have not yet decided to deploy an MDSS may want to move is this direction in a more step-wise fashion without committing to a costly, fully evolved MDSS system initially. There is benefit in offering a relatively inexpensive tool focused on helping maintenance operators better forecast the timing and type of precipitation at the beginning of a storm event.

The MDSS offered a tool that helped MaineDOT integrate a variety of critical weather data into a useful GIS platform. These capabilities alone meet the most frequently expressed needs of DOTs that want a tool that can help them better time their pre-treatment decisions and determine the correct materials for the conditions they are going to face at the front end of a storm. DOTs want to know start time, precipitation type, anticipated amount of precipitation, and duration. An MDSS that could improve a DOT's ability to only do that would be very valuable, and may be all that some state DOTs want or need.

The transportation community, including federal and state agencies, should continue to support the development of several different MDSS systems that offer state DOTs a choice of capabilities, functionality, and cost. This kind of environment helps encourage innovation and attention to meeting a range of different needs in different parts of the country. The MDSS deployed by MaineDOT raised awareness throughout the state of the value and potential of a tool that could supplement their existing weather forecasting and management tools with a set of capabilities they didn't have previously. Transportation agencies also can support training to capitalize on this growing awareness and encourage the further development and wider use of MDSS tools to help improve overall transportation safety, mobility, and productivity.

1 Introduction

1.1 Background

This report presents the results of a case study evaluation of a Maintenance Decision Support System (MDSS) project under a program funded by the U.S. Department of Transportation's (USDOT) Intelligent Transportation Systems (ITS) Joint Program Office. The Federal Highway Administration (FHWA) Road Weather Management Program (RWMP) has sponsored development of a prototype Maintenance Decision Support System (MDSS). The federal MDSS prototype software modules are available to private vendors who have utilized them to develop decision support applications tailored to the needs of state Departments of Transportation (DOTs). An MDSS was offered to the Scarborough crew of the Maine Department of Transportation (MaineDOT) by Meteorlogix/DTN. The DTN system, known as WeatherSentry, includes MDSS capabilities. Experience to date suggests that significant benefits are possible from the use of an MDSS, including improved productivity (e.g., reduced material costs, more efficient use of labor), enhanced mobility, and increased safety.

The MDSS offers guidance for maintenance managers and engineers that provide a forecasts of weather and pavement conditions and recommendations on efficient maintenance treatment strategies. This research is being conducted to understand the role, benefits, and potential cost savings associated with the use of an MDSS by MaineDOT on a segment of interstate in the vicinity of Portland, ME, based upon a comparison of historical winter maintenance practices and those practices facilitated through the use of the MDSS tools.

State DOT operations and maintenance personnel have many different tools available to help them maintain the safety and performance of their transportation systems. Among the several tools available in support of winter maintenance, an MDSS offers unique capabilities in support of operational decision making, pavement treatment, and resource deployment. These capabilities include enhanced corridor-specific weather and pavement condition forecasts, tailored road treatment guidelines, a GIS-based platform that integrates key elements previously addressed separately, and an educational value that encourages new and more effective ways to assess and respond to the effects of weather on the transportation infrastructure.

An MDSS offers a variety of benefits discussed in this report that include, for example, the potential to fine tune the timing of key decisions, such as when to mobilize, when to pre-treat, how much anti-icing chemicals to use, and where to assign and apply the various resources available to the DOT (labor, materials and equipment). The actual benefits experienced by a user of an MDSS will depend on many factors that must be considered in managing a storm event, and these factors are explored in this assessment of MaineDOT's initial MDSS deployment.

The evaluation team, under a contract with the USDOT, worked with MaineDOT to identify and characterize the benefits and lessons learned from deploying an MDSS in support of winter maintenance operations during the winter of 2006-2007. This assessment examined the institutional challenges faced by MaineDOT's Scarborough crew and the strategies they employed as they used a variety of tools, including the MDSS, to fight each of the winter storm events they faced. The assessment also described the resources and costs incurred by this crew in terms of labor, equipment, and materials across each of these events.

The evaluation sought to understand how the MaineDOT Scarborough crew traditionally handled these events and the role that the MDSS played in supplementing or changing their traditional approach to decision making and operational activities. Using a detailed event reconstruction approach, data were collected for a dozen winter storm events that required a maintenance response, in order to characterize the uses of the MDSS as a maintenance tool, versus not using an MDSS (i.e., how maintenance operations would have been conducted prior to having access to an MDSS). Lessons learned were derived from the reconstruction of these storm events that may be of use to other state DOTs considering implementing an MDSS technology.

1.2 Pathways to Benefits

There are many possible ways, or pathways, by which an MDSS could potentially offer benefits to a DOT winter maintenance operation. Some may be achieved more quickly or more easily, and some may be obvious and some may be less so. In order to facilitate the identification of benefits and lessons learned in this assessment, as well as to offer practical suggestions regarding how MaineDOT might consider using the MDSS to their benefit, a set of possible pathways was developed as shown in Table 1.

Table 1 illustrates pathways that link the kinds of information provided by an MDSS, both before and during a storm event, with the potential for benefit outcomes that could be experienced by any DOT winter maintenance division. As illustrated in the table, an MDSS can offer benefits by affecting the nature, timing, or effect of many of the key decisions that the maintenance operators, supervisors and crew must make in the course of fighting a winter storm. The pathways to the achievement of benefits are not always clear; a particular forecast from an MDSS may be considered in conjunction with several other pieces of information from an MDSS or other sources as well, and only taken together will they inform the best decision by DOT personnel. It will not always be possible to uniquely associate a particular benefit with an MDSS because the decision processes may be very complex and hard to disentangle. However, an MDSS is structured to integrate many of the informational elements shown in Table 1 in a way that enhances the efficiency and quality of decision making. While many of the elements in Table 1 may be separately available from a variety of service providers, the MDSS offers a significant improvement by linking key elements together through an accessible user interface.

One of the main ways that DOTs have used MDSS forecasts is for the timing of the start of precipitation, usually snow, to determine the optimum time for calling in their crews and when to initiate pre-treatment of the roads. Concurrently, the forecast of precipitation type, coupled with other factors such as forecasts of wind speed and pavement temperature trends, allow the DOT to decide what types of materials and how much of those materials to apply to the road surface.

Table 1. MDSS Pathways to Benefits

<table>
<tr><th>MDSS Provided Information</th><th>Decision Paths to Benefits</th><th>Potential Benefits to a DOT</th></tr>
<tr><td rowspan="2">Forecast timing of start of storm event</td><td>• Determine time to call in crews (e.g., closer to onset of event)</td><td>• Savings in crew labor hours; reduced overtime hours; reduced down time</td></tr>
<tr><td>• Determine optimal time to begin pre-treatment</td><td>• Reduce amount of materials needed for pre-treatment or subsequent treatment(s)</td></tr>
<tr><td>Forecast timing of end of storm event</td><td>• Determine time of final treatment and plowing.
• Determine time to send crew home.</td><td>• Savings in crew labor hours
• Savings in type (less costly) and amount of materials used.
• Shorter periods of reduced mobility and impaired safety levels.</td></tr>
<tr><td>Forecast precipitation type (use with wind speed to forecast blowing snow and low visibility potential).</td><td>• Select material type and truck loading time.
• Determine if pre-treatment is needed</td><td rowspan="2">• Savings in amount of materials used.
• Avoid using more costly or inappropriate materials.
• Improved crew and traveler safety.
• Provide appropriate traveler information.</td></tr>
<tr><td>Forecast precipitation amount (use with precipitation type to forecast potential for drifting snow or flooding)</td><td>• Select material type(s) and application rate.
• Determine if pre-treatment is needed.</td></tr>
<tr><td>Forecast pavement temperature and trend (use in combination with forecast type and precipitation amount; dew point, humidity.)</td><td>• Determine treatment routes
• Determine treatment start and stop time
• Select material type(s) and application rate
• Decide whether pretreatment is needed.
• Determine frost potential by location.</td><td>• Savings in amount of materials used.
• Ability to maintain Level of Service (LOS) and road safety.
• Savings in labor, equipment maintenance, fuel costs, and truck miles.</td></tr>
<tr><td>Forecast air temperature and trend. (use in combination with pavement temperature and precipitation amount)</td><td>• Select material type(s) and application rate.
• Adjust plans based on extreme cold forecast.</td><td rowspan="2">• Above benefits associated with appropriate use of labor, materials and equipment.</td></tr>
<tr><td>Differential forecasts by geographic location</td><td>• Adjust treatment strategies based on route-specific conditions.</td></tr>
<tr><td>Recommended treatment</td><td>• Provides guidance consistent with MaineDOT standard procedures.</td><td>• Coupled with other factors, leads to reduction in total treatment costs.</td></tr>
<tr><td>Alerts in advance of event (provides early warning of event)</td><td>• Consult the MDSS</td><td>• Better preparation and more efficient maintenance operations.</td></tr>
<tr><td>Alerts during event</td><td>• Consult the MDSS.
• Estimate timing and type of mid-term and final treatments.</td><td>• Leads to all above benefits</td></tr>
<tr><td>Enhanced weather and road condition information overall (MDSS plus other sources)</td><td>• More timely and route-specific information shared within and between maintenance crews.</td><td>• Savings in labor, equipment, materials and operational efficiency</td></tr>
</table>

Many state winter road maintenance operations have not had the benefit of precise forecasts of many key decision parameters in the past, such as air temperatures, pavement temperatures, bridge temperatures, bridge frost, dew point, and wind speed hours in advance. While MaineDOT has had access to weather services and a contract meteorologist to provide forecasts of many different weather parameters, they have lacked many of the MDSS capabilities and a common integrated platform for viewing and managing the information. MaineDOT also has lacked a system that could consolidate these weather parameters into treatment recommendations that are specifically targeted to defined geographic points within their maintenance region. In the past, operators have had a variety of state and local general weather forecasts of uncertain accuracy. They, like others in MaineDOT, have relied on Road Weather Information Systems/ Environmental Sensor Stations (RWIS/ESS), Automated Surface Observing Systems (ASOS), neighboring states and crews on the road throughout the state, plus the experience of their own crews, to provide current condition information as input to decisions. Now MDSS systems are offering more sophisticated forecasts that have the potential to change how maintenance decisions are made. The results of those decisions are expected to include more efficient deployment of staff, application of materials, and use of equipment with benefits measured in terms of road safety, mobility and operational efficiency better than was possible before. While this assessment recognizes there is likely to be a learning curve associated with the adoption and use of an MDSS in Maine, it sought to identify these kinds of benefits through an examination of how the Scarborough crew made use of the MDSS in dealing with each winter storm event.

2 Evaluation Scope and Objectives

2.1 Problem Statement

Weather presents a serious challenge to safety and mobility on our national system of roads and highways. Winter storm events present obvious snow and ice hazards to driving, but even relatively small weather events, such as light rain or occasional fog can dramatically impact traffic flow and safety at any time of year. The FHWA reports that in the presence of adverse road weather conditions, every year on our highways "nearly 7,400 people are killed and over 690,000 people are injured."[1] In addition to the obvious safety implications of adverse weather on roads, weather impacts can be very costly in terms of lost time due to congestion, lost wages and productivity, and the costs to state DOTs seeking to maintain mobility and safety on their road system.

The FHWA seeks to address these weather-induced transportation challenges proactively and in a variety of ways, such as through the provision of better information, advanced warning of weather events, more precise knowledge of the timing, location and extent of likely weather impacts, better integration of weather into traffic operations, and application of advanced tools to support decision making. Solution strategies include development and promotion of new technology and tools as well as institutional and organizational culture changes that encourage awareness building, knowledge transfer, and the adoption and effective use of these tools.

The deployment of an MDSS in Maine offered an opportunity to assess the ability of this tool to support MaineDOT in better addressing the challenges presented by winter weather to their road maintenance activities. The expectation is that an MDSS offers state DOT maintenance personnel a tool that can help them achieve greater benefits and reduced costs; that is, the benefit-to-cost ratio should increase. This evaluation was initially designed as a system impact study to measure the effect of an MDSS on this ratio but the scope was adjusted due in part to the very limited quantitative data related to the effects of an MDSS on MaineDOT's maintenance operations. A case study evaluation more accurately reflected the conditions encountered in Maine and offered a better opportunity to identify findings and benefits associated with an MDSS that will be of broad value to other states. The primary objective of this case study evaluation is to understand the uses and value derived from an MDSS in one location to add to a body of evidence that could support MDSS deployments among other DOTs.

2.2 Scope of Evaluation

This evaluation developed a case study of an MDSS during the winter season of 2006-2007 in and around the Portland, Maine metropolitan region of southern Maine (MaineDOT Region 1). The evaluation was initially designed to collect baseline data before deployment and use of the MDSS followed by post-deployment data collection that would allow an analysis of the differences between the before and after periods as a method to identify changes due to the use of this type of tool. However, it was apparent from the start of the evaluation that the usual conditions for a before-after system impact study design were not in place under the circumstances. The MDSS deployment had occurred prior to the initiation of the evaluation, and

[1] http://ops.fhwa.dot.gov/Weather/q1_roadimpact.htm.

no time was provided for the users of this system to adjust and adapt to the new technology. The winter had already begun, and data collection could not be delayed. There was essentially no distinction between baseline and post-deployment periods.

A decision was made part way through the evaluation to modify the approach to conduct a case study to address the following specific goals:

- Identify lessons learned from MaineDOT's experience using an MDSS.
- Identify effective strategies for deploying an MDSS.
- Identify institutional issues and implementation costs faced by MaineDOT in integrating an MDSS into their winter maintenance decision processes and how these issues were addressed.
- Assess how an MDSS supplements the suite of tools available to MaineDOT for making winter maintenance decisions.
- Assess the operational use of an MDSS by reconstructing each of the winter storm events and Maine DOT's management of those events.
- Assess the potential benefits that an MDSS could offer MaineDOT if it were utilized more comprehensively.

This approach involved a focus on the institutional processes and experiences of the MaineDOT Scarborough crew as they experimented during this first winter period with an MDSS and sought to find effective ways to use this new tool in support of their maintenance operations. The evaluation methods, that were applied initially and involved a detailed reconstruction of the Scarborough crew's strategy for responding to each new winter storm event, provided a detailed understanding of these institutional processes. This allowed for a seamless and constructive transition from a system impact study design to a case study design for the evaluation.

3 MaineDOT MDSS Deployment

3.1 Introduction

MDSS functions were provided to MaineDOT on a subscribed, Internet-based service. The MaineDOT users of the MDSS were able to access the application over the Internet from either work or home computers, logging in to an account set up for their use. Seven user accounts were set up for MaineDOT headquarters in Augusta, Maine and each of the of the five maintenance regions. This evaluation focused on the experiences of the Scarborough crew in Region 1 and their initial use of the MDSS during the winter months of 2006-2007. This chapter describes the MDSS capabilities and interface provided to MaineDOT users.

3.2 Study Route and Forecast Points

MaineDOT defined the forecast points where MDSS-specific information would be provided along the study route in southern Maine. The forecast points were distributed along the study route to provide discrete points that could serve as a proxy for a route-based forecast. The initial forecast point was the Yarmouth ESS site that is located about 4 miles beyond the north end of the study route. Three additional forecast points were added along I-295 served by the Scarborough crew to enhance the representativeness of the area being examined in this evaluation.

A total of four forecast points were used in support of the winter maintenance operations using the MDSS. The new forecast points were incorporated into the MDSS and made available to MaineDOT.

- I-295 South Portland (new point)
- I-295 Portland (new point)
- I-295 Falmouth (new point)
- I-295 Yarmouth (ESS site north of evaluation route)

In the federal MDSS prototype, ESS are used to provide ground truth to allow the MDSS pavement forecast algorithm to perform “forward correction” to improve the accuracy of forecasts. Because the only ESS in Region 1 was located north of the selected study route, the MDSS and MaineDOT relied primarily on the Portland International Jetport ASOS (providing instrumented, radar and human observation) as a source of ground truth observations, supplemented by the observations of the maintenance crews and reports from the New Hampshire Department of Transportation (NHDOT).

As shown in Figure 1, the study route was a 12-mile section of I-295 freeway that traverses through downtown Portland between Falmouth to the north and I-295 and I-95 junction to the south. The Region 1 maintenance facility that participated in this study is located in the Scarborough area near the southern end of the study route.

The northern portion of the study route is primarily suburban and rural freeway that runs along the Atlantic coastline. The southern portion is the main commute route that serves the Portland metropolitan area and the Portland International Airport (southwest of Portland). Further south, the study route merges with I-95 (tolled). The study route encompasses complex micro-climate environments that are variably influenced by proximity to the ocean and that present a challenge in accurately forecasting local road weather conditions.

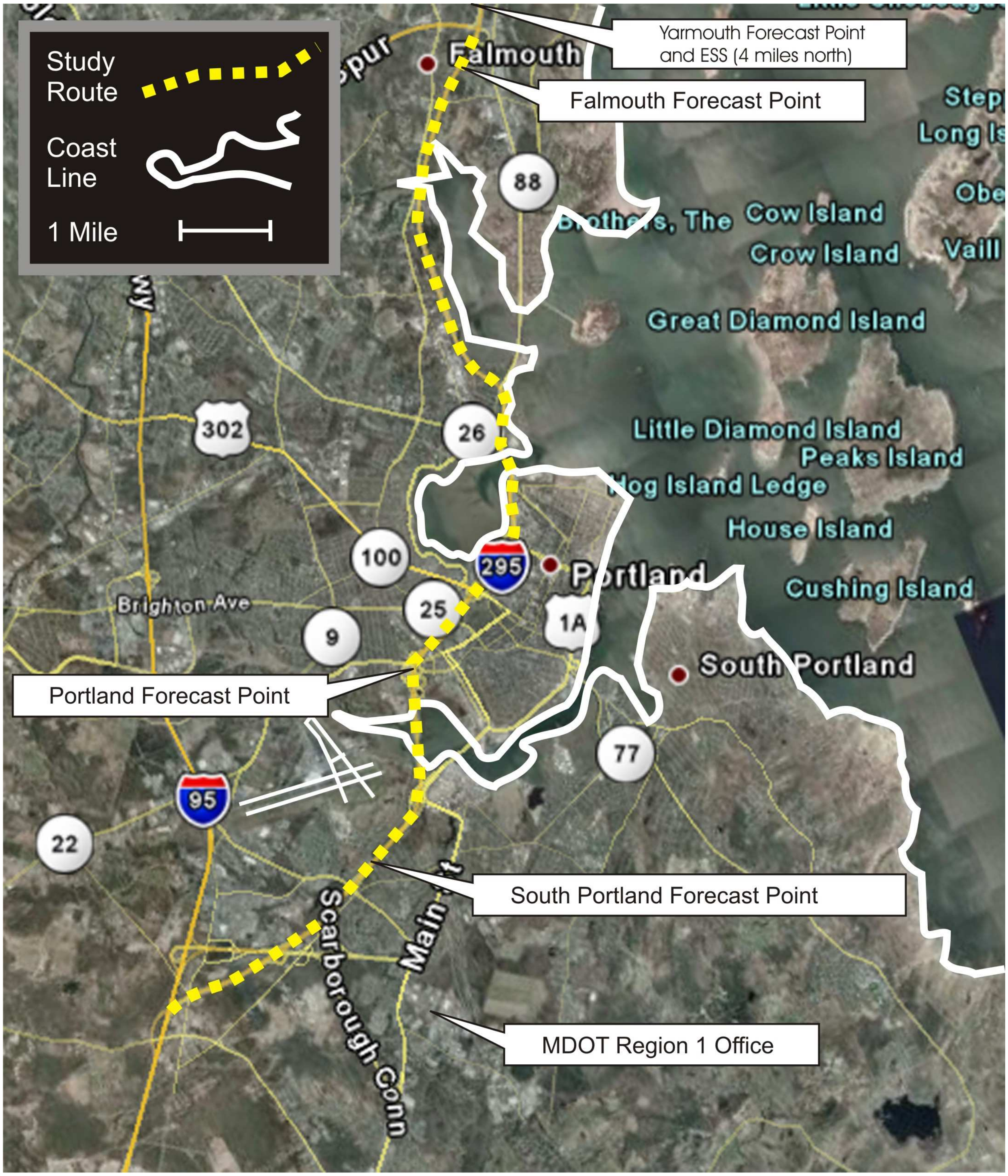

Figure 1. Forecast Points along I-295 Study Route, Maine

3.3 Forecast Information Provided by the MDSS

A comprehensive set of road weather information was made available to the MaineDOT maintenance crew through the MDSS. Major data elements were provided in hourly forecasts that included the following components:

- Weather condition (icons indicating primary weather conditions)
- Weather (description of primary weather conditions)
- Temperature (air)
- Feels like (air temperature considering wind chill)
- Wind direction
- Wind speed/gust (miles per hour)
- Dew point
- Humidity (percent)
- Precipitation chance (percent)
- Precipitation type
- Precipitation amount (liquid equivalent in inches)
- 24 hours snow accumulation (10:00AM-10:00AM)
- Blowing snow potential
- Bridge temperature
- Road temperature
- Bridge frost likely? (yes/no)
- Road frost likely? (yes/no)
- Treatment recommendations

The hourly forecast interface automatically highlighted the road weather parameters that exceeded a pre-determined threshold that could be set by MaineDOT. Up to 72 hours of forecast were provided, and the first 24 hour period provided the MDSS-related pavement condition forecast and treatment recommendations. The time period for the pavement forecast is selectable by the DOT. A DOT can request this set of information for any or all of the designated forecast points.

3.4 MDSS Alerts

Location-specific alerts are configurable by specifying thresholds for selected forecast parameters (e.g., precipitation greater than or equal to 0.01 in) and/or associating the locale with the issuance of National Weather Service (NWS) warnings. The alerts can be viewed on the MDSS, and/or sent via e-mail or to cell phones via text messaging.

A list of variables is available for configuring alerts, and each variable can be enabled independently. However, no logical operations can be applied on multiple variables to monitor a scenario of interest. Each enabled variable will trigger an alert if the associated criterion is met (e.g., temperature greater than the specified threshold). Because the alerts are location specific, subscription to multiple alerts (by variable) for multiple locations increases the likelihood of receiving a large number of potentially similar alerts caused by the same weather event.

Precipitation alerts can be set based on a selected intensity threshold and an early warning lead time. Thus, a DOT can indicate when they would like to be notified in advance of the start of precipitation by the intensity of the forecast precipitation. Alerts can be set for each forecast point with regard to selectable precipitation types, proximity of lightning, wind speeds, visibility, forecast temperatures and humidity, NWS alerts, and observed conditions (based on available ESS, ASOS, and other ground truth sources).

MaineDOT elected to receive alerts related to precipitation type and timing and NWS advisories for all of their forecast points. The use of alerts is meant to supplement the web-based MDSS. However, each alert only contains a single variable description that ties to a location (e.g., snow observed at I-295 Portland). After receipt of an alert, users are expected to log on to the MDSS to be fully briefed on the situation. A "quiet time" option is available to disable the alerts during specified non-work hours (e.g., night to early morning). The MaineDOT maintenance crew chose to exercise that option, thus preventing receipt of any text messaging, alerts, and e-mail during the specified quiet hours. During these quiet periods the crews relied on MaineDOT's 24-hour operations center to assess the appropriate time to call them out for late evening or early morning maintenance activities.

3.5 MDSS Treatment Recommendations

Recommended treatments associated with different pavement temperature ranges were provided by MaineDOT for incorporation into the MDSS, as shown in the Appendix (Table A). The MDSS provides the user with a recommended treatment when the atmospheric and pavement temperature forecasts meet associated threshold values. Internally, the main components of the MDSS treatment recommendations are:

- Atmospheric weather forecasts, including forecasts of air temperature, dew point, and other surface weather elements, and precipitation;
- Pavement temperature forecasts; and
- A rules engine that determines the weather scenario, and then applies the appropriate treatment recommendation.

Pavement forecasts are created using the atmospheric forecasts as input. The pavement model (SNTHERM) assumes that all snow is removed from the roadway surface as soon as it falls to a predetermined blade depth based upon recommended treatments. The model outputs a 24-hour forecast of pavement temperatures and pavement frost, again using the MDSS prototype algorithm (unrelated to SNTHERM). Pavement temperature forecasts are updated every hour.

While it is possible to program treatment recommendations for different weather scenarios and temperature range combinations, MaineDOT chose to implement a set of treatment recommendations regardless of weather scenarios and based on a set of pavement temperature ranges they specified. The MaineDOT recommendation is provided in terms of a range of chemical (salt) application rates (e.g., 150 to 250 pounds per lane mile (pplm) for pavement temperature range from 28ºF to 32ºF). This leaves discretion to the crew, including the decision whether or not to pre-treat the surface with salt brine (typically applied two hours before the precipitation arrives).

Given the length of the evaluation route (12 miles), it typically takes two snow plow trucks and about one-and-a-half hours to traverse both directions of the I-295 corridor between Falmouth and I-95, depending on traffic and the severity of the weather conditions. For the duration of a typical storm event, multiple treatments may be needed.

4 MaineDOT Maintenance Operations

This chapter provides a description of MaineDOT's winter maintenance operations relevant to this evaluation.

MaineDOT is responsible for maintenance of the state highway system, and in Scarborough in Region 1 they have 18 crew members and 11 trucks. Figure 2 shows the location of Region 1 in southern Maine. MaineDOT has provided an MDSS to all their crews as of the end of winter 2005-2006, though most were initially exposed to the system by October 2006.

Two trucks and crew members are typically assigned to the segment of I-295 that is the subject of this evaluation. MaineDOT is interested in applying new technology, such as an MDSS, to enhance efficiency, safety, and consistency in their maintenance operations throughout the state.

The MaineDOT operations center in Augusta coordinates information dissemination throughout the state for winter road maintenance operations. MaineDOT communicates with NHDOT for advanced storm warnings, and the various maintenance crews communicate with each other on a regular basis. The Scarborough crew that operates out of Region 1 used two of their 11 trucks under most circumstances to handle the maintenance requirements on the test segment of I-295.

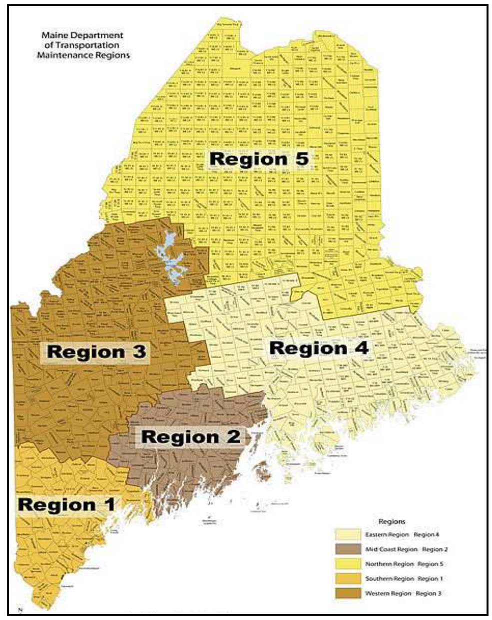

Figure 2. MaineDOT Maintenance Regions

MaineDOT employs a Maintenance Activity Tracking System (MATS) that has served as a data repository for labor, materials and equipment usage, and unit rates and costs for each of these categories since 2000. Each crew member enters his daily work report into MATS, and these reports are reviewed and approved by maintenance supervisors for payroll. The staff is paid based on the MATS labor hour entries, and these reports must be completed by the following day. Storm event data also are entered into the daily MATS report to document each storm event. A storm that spans across multiple days can be identified in the daily reports. This includes information on precipitation type (selected from categories in a drop-down menu) at the beginning and end of the storm, the date and time of the start and end of the storm, and the actions taken by the maintenance crews, also date and time stamped. Labor time and materials applied to the test segment of I-295 can be extracted from the daily MATS reports, along with the hours charged by the individual crew assigned to this road segment. MaineDOT generated separate MATS reports throughout this evaluation period that focused exclusively on the activities in the test corridor. Resource usage, including vehicles and materials are recorded daily in MATS as well.

The MaineDOT Scarborough crew has traditionally taken a conservative approach to road maintenance before and during winter storm events, in large part because this section of I-295 is a heavily used high priority roadway. For example, they tend to use higher application rates to treat the road surface at the start of a storm in order to increase the likelihood that a heavy treatment will last throughout the storm and reduce the amount of resources needed for plowing and other follow-up activities. If they observe that the snow is sticking to the road surface, then they will add additional salt. They will pre-wet the salt with either magnesium chloride or calcium chloride when the air temperature drops below the range of 22 to 24 degrees Fahrenheit. In warmer situations they will try to use salt brine for pre-wetting as it costs less than the other two chemicals.

Historically, MaineDOT has primarily based their winter road treatment decisions on the time of day or night, traffic volumes and how their treatments are reacting to traffic. For example, heavy traffic may rapidly disperse pavement chemical applications. The on-road crews inspect how the tires of vehicles using the road are interacting with accumulated precipitation and the chemical mix on the road surface, in addition to the pavement temperature readings from the plow's onboard infrared pavement temperature sensor, to make judgments about subsequent treatment materials, amounts and timing. MaineDOT has a night patrol and a storm patrol that are typically on the road before a storm event evaluating conditions in real time, digesting information coming in to their radio system from a variety of sources (including their crews and other crews to the north and south of their position), and will notify the operations center when crews need to be called out.

The MaineDOT plow trucks currently only record pavement temperature using an onboard infrared pavement temperature sensor (Figure 3) at the beginning and the end of a session on the road, though readings can be made at any location. These pavement temperature readings are used to support their treatment decisions. However, the lack of location reference in the infrared pavement temperature data hinders the ability of the evaluation to assess variation by geography.

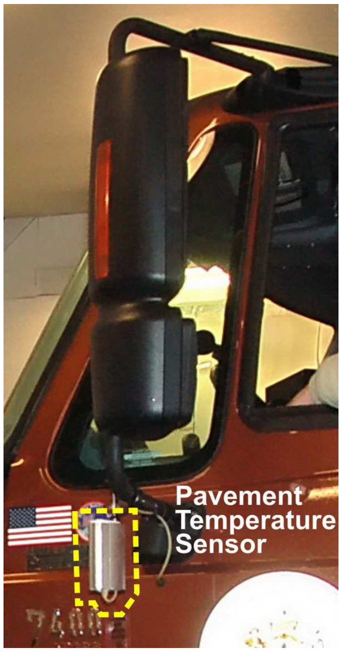

Figure 3. Pavement Temperature Sensor

The MaineDOT Scarborough district radio room has been moved to and consolidated with the 24-hour operations center at MaineDOT's headquarters in Augusta. Weather trends affecting Maine are often confirmed with NHDOT through their turnpike toll booth personnel and are passed on to the MaineDOT crew supervisors. NHDOT has often provided MaineDOT with advance notice of storms before they arrive in the Portland area. This process is still utilized in addition to now using the MDSS and the alerts it provides directly to the Scarborough maintenance crew via phone and email.

5 Evaluation Approach and Methods

5.1 Introduction

The methodology used to assess the benefits and lessons learned associated with the use of an MDSS by the MaineDOT Scarborough crew involved a careful tracking of each of 12 winter storm events that occurred during the winter of 2006-2007, coupled with reconstruction of the crew's decision processes and treatment actions throughout each event. The documentation of the event reconstruction involved a combination of the Scarborough crew maintaining a record of their actions and their uses of the MDSS prior to and during each storm event, and a post-event telephone interview with the crew and their supervisor conducted by the evaluation team. This approach allowed for an understanding of the role played by the MDSS under the conditions faced in each storm and the factors that influenced how the decision support tool was used and what types and magnitudes of benefits were afforded by that usage.

5.2 Storm Event Reconstruction

MaineDOT employs MATS to aggregate daily statistics on labor, materials and equipment usage and costs, plus the timing and nature of their treatments, for each storm event. Each event is assigned a storm number. This report examined only those storm events that required an action on the part of the MaineDOT Scarborough crew that also included input from the MDSS. Some of the early storm events that occurred in December 2006 (MATS events #1, #2, and #4) involved minor actions, such as treating a frosted bridge deck, before the MDSS was being consistently used. This evaluation tracked in detail 12 events, beginning with MATS event #3, and using a consecutive numbering beginning with Event #1.

Figure 4 below illustrates the timing of winter storm events that resulted in a maintenance response by MaineDOT Scarborough crews. The first twelve of these events were reconstructed in detail in this evaluation. The remaining six events were summarized briefly.[2]

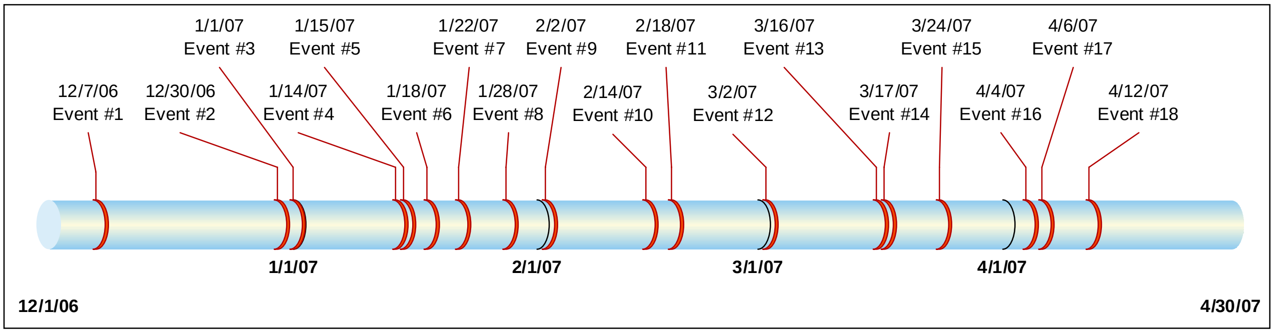

Figure 4. Start Dates for 2006-2007 Winter Storms in Scarborough Area, Maine

[2] A decision was made during the Interim Briefing held in Portland, ME on March 7-8, 2007 to focus from that point forward only on bridge frost events that might occur because there were essentially no new insights emerging from the event reconstruction after the dozen already covered. In fact, no bridge frost events occurred after that time.

Each reconstructed storm event, with exceptions in the early events due to lack of data, included the development of a set of components that are illustrated and discussed below using a single example event that occurred in mid-February 2007.

- A table showing the key MATS statistics for the event. An example of one of the storm events is provided in Table 2. The data show the type and amount of precipitation as recorded by the crew, along with the start and end of the storm and the actions taken. "Number cycles" represent the number of times the crew salted or plowed and the time period and duration for those actions. The MATS report serves as the basis for crew time reports, and it documents all the labor and material costs incurred in dealing with each storm event.

Table 2. MATS Statistics for Example Storm Event.

MaineDOT Scarborough Crew Event Report			
Event Type (amount)	**Start Date/Time**	**End Date/Time**	**Duration**
Freezing Rain; Sleet; Wet and Dry Snow (10.0 in.)	02/14/07 at 02:30 AM	02/15/07 at 03:00 AM	24.5 hours
MaineDOT Actions (number cycles)			
Anti-Icing (0)	---	---	0 hours
Salting (10)	02/14/07 at 03:30 AM	02/15/07 at 10:00 AM	30.5 hours
Plowing (~30)	02/14/07 at 04:00 AM	02/15/07 at 03:30 PM	35.5 hours
MaineDOT Resource Usage		**Quantity**	**Cost**
Labor	3 drivers	77 hours	$1,574.02
Equipment (incl. fuel)	3 trucks	65 hours	$2,260.70
Materials	Salt Brine	3,250 gallons	$487.50
	Magnesium Chloride	0 gallons	---
	Salt	108.57 tons	$5,441.53

- A table showing the observed weather conditions as recorded automatically at the Portland Jetport. The observational data that coincide with the start and end timing of the event as designated in the MATS table are highlighted, with a two hour buffer (shown in italics) at the beginning and end to illustrate more context for each event. As shown in Table 3, these data are not provided precisely on the hour. Precipitation is provided in inches of liquid equivalent. Direct observational data on snow depth was not available, but this was provided in the MATS reports based on crew observations (see Table 2). Wind speed shows the prevailing speed along with recorded gusts. In this example, the event was characterized by wide variability in the weather conditions (precipitation type), including light snow, snow, heavy snow, fog, mist, freezing fog, and freezing rain. These kinds of borderline conditions between rain and snow from one hour to the next are very difficult to forecast in advance. In addition, the Portland Jetport ASOS constitutes only one observation point that can not represent conditions across the entire study area.

Table 3. Observed Weather Conditions, Portland Jetport ASOS, for Example Storm Event

Date	Time (EST)	Weather Conditions	Temperature (ºF)		Wind Speed |Gust (mph)	Precipitation (inches)
			Air	Dewpoint		Recent 1 hr
02/14/07	*12:51 AM*	*Overcast*	*15*	*-2*	*6*	
02/14/07	*01:51 AM*	*Overcast*	*14*	*-1*	*7*	
02/14/07	02:51 AM	Light Snow	14	0	9	
02/14/07	03:51 AM	Light Snow	12	4	8	
02/14/07	04:51 AM	Light Snow	11	5	9	
02/14/07	05:51 AM	Light Snow Fog/Mist	10	6	8	0.03
02/14/07	06:51 AM	Snow Freezing Fog	10	6	9	0.11
02/14/07	07:51 AM	Snow Fog/Mist	10	6	9|20	0.05
02/14/07	08:51 AM	Snow	11	6	12	0.01
02/14/07	09:51 AM	Snow	11	6	14|20	
02/14/07	10:51 AM	Light Snow	11	6	15|20	0.01
02/14/07	11:51 AM	Light Snow	13	8	12	
02/14/07	12:51 PM	Light Snow	14	9	13|23	
02/14/07	01:51 PM	Snow	17	12	18|28	0.01
02/14/07	02:51 PM	Light Snow and Breezy	17	12	24|35	
02/14/07	03:51 PM	Heavy Snow Freezing Fog Breezy	17	14	25|33	0.10
02/14/07	04:51 PM	Snow Freezing Fog	18	15	18|29	0.09
02/14/07	05:51 PM	Light Snow Fog/Mist Breezy	18	15	22|29	0.06
02/14/07	06:51 PM	Light Snow Fog/Mist	19	15	18|29	0.04
02/14/07	07:51 PM	Freezing Rain Fog/Mist Breezy	21	18	23|36	0.01
02/14/07	08:51 PM	Light Snow Fog/Mist	22	19	18|30	0.02
02/14/07	09:51 PM	Light Snow Fog/Mist Breezy	22	19	21|28	0.03
02/14/07	10:51 PM	Freezing Rain	23	20	20|30	
02/14/07	11:51 PM	Light Snow Fog/Mist Windy	22	18	26|46	0.02
02/15/07	12:51 AM	Light Snow Fog/Mist Breezy	22	18	23|38	
02/15/07	01:51 AM	Overcast and Windy	21	13	28|36	
02/15/07	02:51 AM	Light Snow	17	10	18|30	0.01
02/15/07	*03:51 AM*	*Overcast*	*17*	*5*	*20|32*	
02/15/07	*04:51 AM*	*Overcast*	*17*	*3*	*20|32*	

Source: NOAA ASOS for Portland, Maine: http://www.erh.noaa.gov/data/obhistory/KPWM.html

- A figure showing a radar image of the storm event at approximately the middle (height) of the storm. This offers a visual sense of the geographic coverage and intensity of the event. The scale illustrates the rate of precipitation experienced at the time the image was captured. A small black circle pinpoints the location of Portland, ME and the test road area. As shown in this example in Figure 5, the storm covers most of the northeastern part of the country, from Pennsylvania into parts of Canada. The most intense precipitation is centered at this time over the Maine study area.

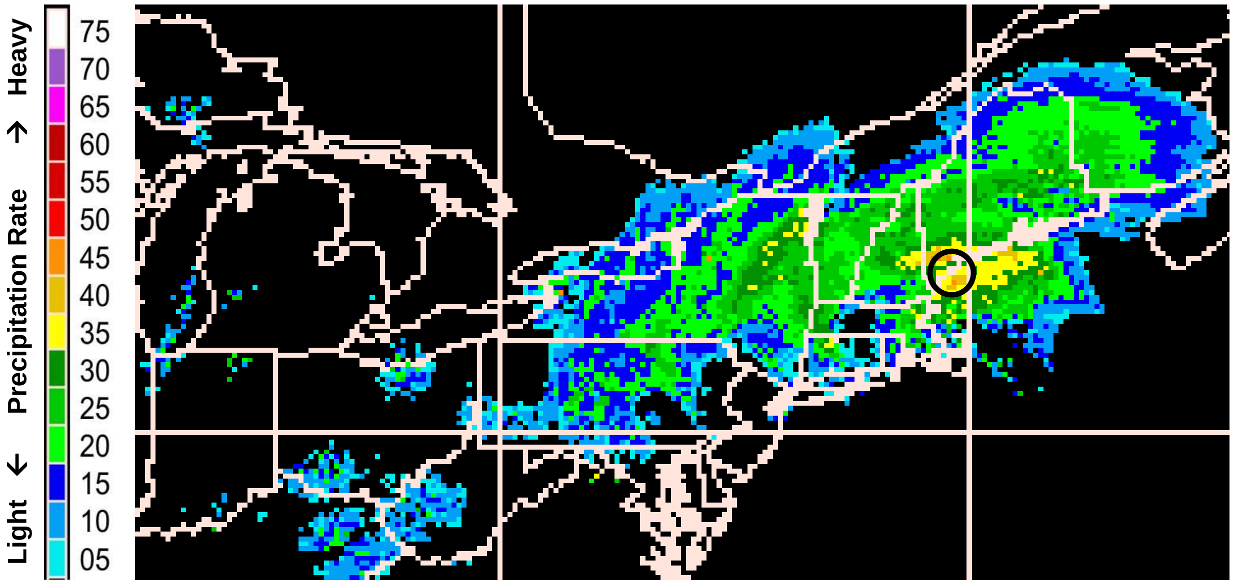

Figure 5. Radar Image of Example Storm Event on 2/14/07 at 4:00 PM

- Two tables showing the MDSS hourly forecasts and treatment recommendations from the MATS designated start and end times of the storm. The exact timing of these forecasts depends on the availability of archived data from the vendor's records.
    i. Table 4 reflects a forecast five and a half hours prior to the start of the storm. The intent was to provide a six hour forecast, but this was not always available from the archived MDSS data. Approximately six hours advance notice provides the MaineDOT Scarborough crew enough time to plan and execute pretreatment of the roadway before precipitation is forecast to begin. This table shows only selected information based on the MDSS forecast for this example event, including forecasted weather conditions by the hour, air and pavement temperature forecast, wind speed, snow fall, and the treatment recommendations (see referenced treatment numbers in the Appendix (Table A). Snow fall is an hourly forecast based on radar imagry and estimated liquid equivalent. In this instance, the forecast 5.5 hours prior to the onset of the storm is for a total snow fall of about 7.6 inches over the duration of the storm, which can be compared with the crew's observation of snow fall after the event of 10 inches and the Portland Jetport ASOS observation of 0.6 inches of liquid equivalent.

Table 4. MDSS Hourly Forecast at 20:00 EST February 13, 2007, 5.5 Hours before Example Event, at Portland

Date	Time (EST)	Weather Conditions	Temperature (ºF)			Wind Speed (mph)	Snow (inch)	Treatment (Appn. A)
			Air	Dewpoint	Pavement			
2/13/07	20:00	Clear	14	-6	17	11	0	
2/13/07	21:00	Clear	13	-4	16	11	0	
2/13/07	22:00	Partly Cloudy	12	-3	16	11	0	
2/13/07	23:00	Partly Cloudy	11	-2	15	10	0	
2/14/07	00:00	Mostly Cloudy	10	-1	15	9	0	
2/14/07	01:00	Mostly Cloudy	10	0	15	8	0	
2/14/07	02:00	Snow	10	0	15	9	0	
2/14/07	03:00	Snow	10	1	14	10	0	5
2/14/07	04:00	Snow	11	1	14	11	0.17	5
2/14/07	05:00	Snow	11	2	15	12	0.46	4
2/14/07	06:00	Snow	11	3	15	13	0.46	4
2/14/07	07:00	Snow	11	4	15	14	0.41	4
2/14/07	08:00	Snow	11	4	15	15	0.56	4
2/14/07	09:00	Snow	12	6	16	16	0.56	4
2/14/07	10:00	Snow	13	7	17	17	0.44	4
2/14/07	11:00	Snow	15	9	18	18	0.64	4
2/14/07	12:00	Snow	16	10	19	18	0.64	4
2/14/07	13:00	Snow	18	12	21	19	0.53	3
2/14/07	14:00	Snow	19	14	22	21	0.53	3
2/14/07	15:00	Snow	20	15	22	23	0.53	3
2/14/07	16:00	Snow	21	16	22	25	0.32	3
2/14/07	17:00	Snow	22	17	23	27	0.26	3
2/14/07	18:00	Snow	23	18	24	29	0.26	3
2/14/07	19:00	Snow	24	19	25	31	0.26	3
2/14/07	20:00	Snow	25	20	26	33	0.54	3

ii. Table 5 reflects a forecast approximately one hour prior to the start of the storm. The anticipated utility of this forecast is greater accuracy, given its proximity to the start of precipitation. This forecast of a total snow fall of 11.3 inches comes quite close to forecasting the snow fall actually observed by the crew (10 inches).

Table 5. MDSS Hourly Forecast at 01:00 EST February 14, 2007, 1.5 Hours before Example Event, at Portland

Date	Time (EST)	Weather Conditions	Temperature (ºF)			Wind Speed (mph)	Snow (inch)	Treatment (Appn. A)
			Air	Dewpoint	Pavement			
2/14/07	01:00	Cloudy	13	-2	15	11	0	
2/14/07	02:00	Snow	10	0	15	11	0	
2/14/07	03:00	Snow	8	1	15	11	0	
2/14/07	04:00	Snow	11	1	14	12	0.25	5
2/14/07	05:00	Snow	11	2	14	13	0.68	5
2/14/07	06:00	Snow	11	3	14	14	0.68	5
2/14/07	07:00	Snow	11	4	15	15	0.41	4
2/14/07	08:00	Snow	11	4	15	16	0.56	4
2/14/07	09:00	Snow	12	6	16	18	0.56	4
2/14/07	10:00	Snow	13	7	17	19	0.44	4
2/14/07	11:00	Snow	14	9	18	20	0.64	4
2/14/07	12:00	Snow	16	10	19	20	0.64	4
2/14/07	13:00	Snow	17	12	20	21	0.53	3
2/14/07	14:00	Snow	19	14	21	22	0.53	3
2/14/07	15:00	Snow	20	15	22	23	0.53	3
2/14/07	16:00	Snow	21	17	22	25	0.32	3
2/14/07	17:00	Snow	22	18	23	29	0.26	3
2/14/07	18:00	Snow	24	19	24	33	0.26	3
2/15/07	19:00	Snow	25	19	24	35	0.26	3
2/15/07	20:00	Snow	25	20	25	34	0.54	3
2/15/07	21:00	Snow	25	21	26	31	0.54	3
2/15/07	22:00	Snow	26	22	26	26	0.54	3
2/15/07	23:00	Snow	27	22	27	19	0.77	3
2/15/07	00:00	Snow	28	22	27	11	0.71	3
2/15/07	01:00	Snow	28	22	27	7	0.67	3

- A figure that illustrates, across the duration of the event, the main components and timing of the Scarborough crew's treatment actions, the MDSS forecasted precipitation type, timing, and air and pavement temperature trends, and the observed weather conditions from the Portland Jetport ASOS. These figures present the data in a 24-hour timeframe. Figure 6 shows in a single figure several of the key components of the example event, including the MDSS forecast, the ASOS observations, and the timing of MaineDOT's maintenance actions across a 24 hour period of the event. A particularly instructive aspect of these figures for each storm event is the display of air and pavement temperature trend forecasts, coupled with the forecast and actual conditions. The MDSS offers similar graphics illustrating trends in forecast parameters. From an event reconstruction perspective, this graphic representation paints a picture of each storm event that includes selected components of the MDSS forecast to aid in interpreting MaineDOT's actions across the course of the storm. It is also useful in visualizing the changes over time in the parameters covered both by the forecasts (MDSS) and observations (ASOS).

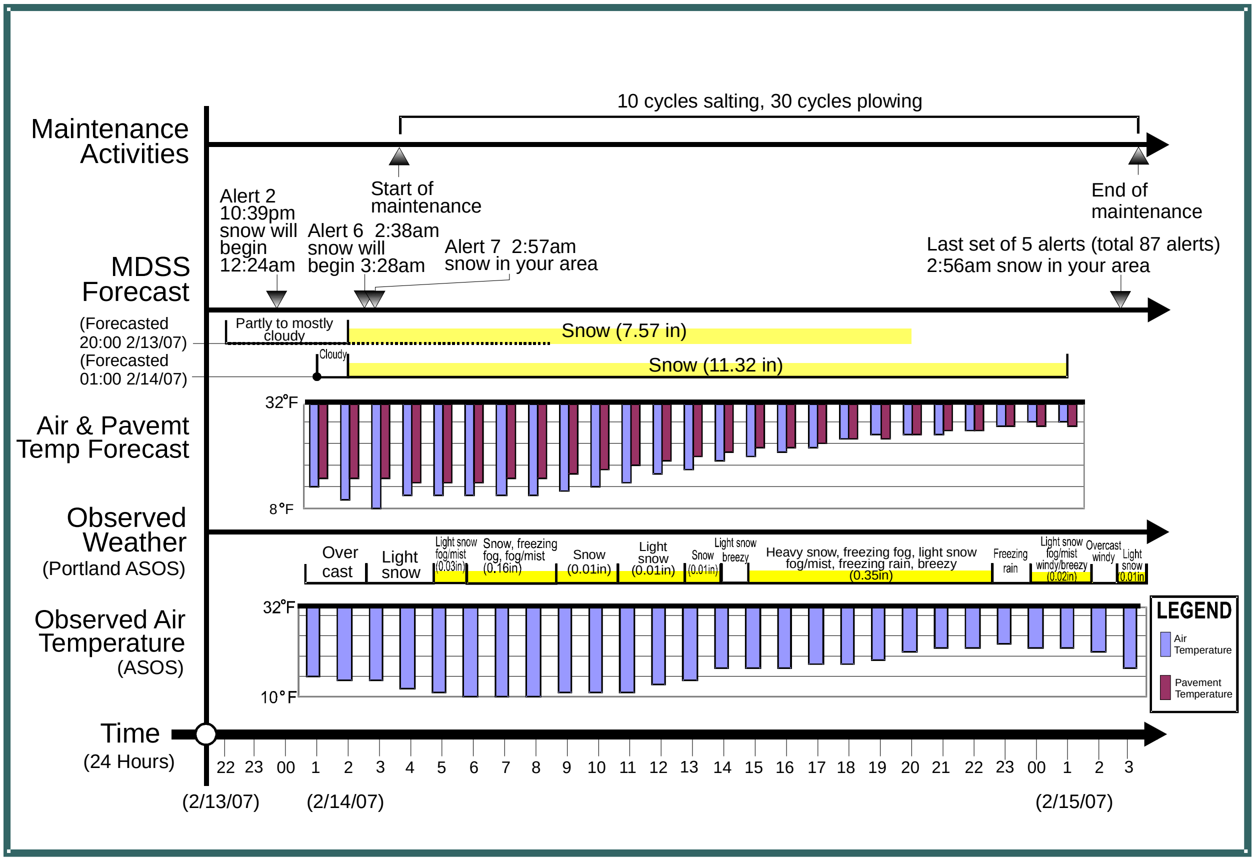

Figure 6. Event Reconstruction Diagram for Example Event

- A table for each event that details all of the MDSS alerts provided to the MaineDOT Scarborough crew before and during the event. Alerts are provided for each of four designated forecast points along the roadway, plus the Scarborough camp. The provision of alerts is based on criteria programmed into the vendor's MDSS web site by the MaineDOT Scarborough crew supervisor. Table 6 shows the initial few and final few alerts provided to MaineDOT over the course of this two day storm event. There were a total of 87 alerts issued. Those shown here give a flavor for the content of these alerts.

Table 6. Alerts from MDSS to MaineDOT for Example Event

No.	Day / Date / Time EST	Alert Location (Forecast Point) and Message
1	Tuesday Feb. 13 at 11:23 AM	For I-295 Falmouth! The NWS has issued a Winter Weather Advisory for your area valid until 6:00 AM 02/15/07
2	Tuesday Feb. 13 at 11:23 AM	For I-295 Portland! The NWS has issued a Winter Weather Advisory for your area valid until 6:00 AM 02/15/07
3	Tuesday Feb. 13 at 11:23 AM	For I-295 Yarmouth! The NWS has issued a Winter Weather Advisory for your area valid until 6:00 AM 02/15/07
4	Tuesday Feb. 13 at 11:23 AM	For I-295 South Portland! The NWS has issued a Winter Weather Advisory for your area valid until 6:00 AM 02/15/07
5	Tuesday Feb. 13 at 11:23 AM	For Scarborough Camp! The NWS has issued a Winter Weather Advisory for your area valid until 6:00 AM 02/15/07

No.	Day / Date / Time EST	Alert Location (Forecast Point) and Message
6	Tuesday Feb. 13 at 10:34 PM	For Scarborough Camp, Snow will begin at 11:40PM EST.
7	Tuesday Feb. 13 at 10:33 PM	For I-295 South Portland, Snow will begin at 11:49PM EST.
8	Tuesday Feb. 13 at 10:40 PM	For I-295 Portland, Snow will begin at 12:12AM EST.
9	Tuesday Feb. 13 at 10:39 PM	For I-295 Falmouth, Snow will begin at 12:24AM EST.
10	Tuesday Feb. 13 at 10:54 PM	For Scarborough Camp, Snow will begin at 12:23AM EST.
83	Thursday Feb. 15 at 2:56 AM	For I-295 Portland! Latest observation from PORTLAND INTL shows Snow in your area.
84	Thursday Feb. 15 at 2:56 AM	For I-295 Falmouth! Latest observation from PORTLAND INTL shows Snow in your area.
85	Thursday Feb. 15 at 2:56 AM	For Scarborough Camp! Latest observation from PORTLAND INTL shows Snow in your area.
86	Thursday Feb. 15 at 2:56 AM	For I-295 Yarmouth! Latest observation from PORTLAND INTL shows Snow in your area.
87	Thursday Feb. 15 at 2:56 AM	For I-295 South Portland! Latest observation from PORTLAND INTL shows Snow in your area.

After all the winter storm events had been reconstructed, documented and analyzed, the benefits of the MDSS across all the events was assessed, and factors that could be shown to influence the extent to which benefits could be experienced from the use of an MDSS were assessed and documented.

5.3 Event Debriefing Interviews

A narrative was developed describing each event based on a telephone debriefing with members of the Scarborough crew and supervisor, coupled with an analysis of the available MDSS data and observational data from other sources. The debriefing discussion followed a structured set of questions that were designed to elicit what happened in each event, how the Scarborough crew responded to the event, what information was used to assist the crew in deciding how to respond to the event, and how information provided by the MDSS was accessed and used in the event. In summarizing the assessment of each reconstructed event, the intent was to determine and describe whether and how the MDSS was of benefit and the magnitude of that benefit, both in terms of costs averted through better timed and more efficient treatment actions and in terms of lessons learned from the response process that could be of value to other DOTs. A key element in these post-event discussions was to explore with the supervisor and crew how they thought they would have responded in the absence of the MDSS as a method for understanding the role and benefit of the MDSS.

MaineDOT agreed to provide their plow truck operators with small digital voice recorders that would allow them to record relevant information during each storm event with minimum distraction. Then they would meet with their supervisor after the event and compare notes on their experiences. The evaluation team drafted a short list of information items to guide the operators in the kind of information they could keep track of during these events. The purpose of the narrative recording was to facilitate remembering the details of the event and to support the debriefing after the event was over in order to have a good record of what happened, what was done, and how available weather information was used. The list included the following items:

- When were you called out for this event?
- What time did you leave the garage?
- For each action you took (e.g., chemical application, plowing, other (define other case by case)
  - What did you do (describe action taken and rationale for that action)?
  - When did you begin the action?
  - When did you finish the action?
  - Where did you perform the action (e.g., describe location, road segment)?
  - Did anything occur that hindered your ability to take that action (e.g., crash, very heavy traffic, other)?
- Did you receive any information or guidance over your radio? If so, what did it say, and what did you do in response? Did you make any change in your action due to the information? Describe. Your assessment of how useful the information was to you.
- Did you request any information? If so what? Discuss why and what you did with it.
- What time did you return to the garage?
- Provide any other thoughts/comments at the end of the event.

The initial process that was worked out during a meeting with the Scarborough crew and their supervisor involved an exchange of information between the crew and the supervisor in which the crew would relay the details from their experiences to the supervisor who would then record the information, as appropriate to each event, in an event record that was jointly designed by the evaluation team and the supervisor (see Table 7).

Table 7. MaineDOT Winter Storm Event Record

Information Type	Data to be Recorded
Transcription of Crew Report (duplicate for each separate crew report)	
Crew members called in	Enter Names:
When called in	Day/Date:
	Time of Day:
Shift timing	Time left garage:
	Time returned to garage:
Assignment (Note that the garage may keep these records.)	Route covered:
	Truck load:
	Materials used (type and amount):

<table>
<tr><th>Information Type</th><th>Data to be Recorded</th></tr>
<tr><td rowspan="6">Event Characteristics</td><td>What was forecast?</td></tr>
<tr><td>What was observed?</td></tr>
<tr><td>Start time of event:</td></tr>
<tr><td>Timing of road whiting over:</td></tr>
<tr><td>Amount of observed snow fall (hourly cumulative record). Note if different by location along route. May record “heavy,” “moderate” or “light”.</td></tr>
<tr><td>End time of event (return to LOS. Discuss if return to LOS varied by segments of the test road):</td></tr>
<tr><td rowspan="2">Effects on traffic (or on crew’s ability to do their job)</td><td>Traffic speed/volume: May record: light, moderate, or heavy.</td></tr>
<tr><td>Describe any incidents/crashes/near misses observed:</td></tr>
<tr><td rowspan="2">Communications during shift</td><td>Describe information (and timing) provided to crew (from Augusta, District HQ, other crews on the road, MDSS specifically):</td></tr>
<tr><td>Describe information from crew to others responding to this event.</td></tr>
<tr><td>Actions taken during shift</td><td>Describe what crew did (pretreatment, plowing, amount of materials used, road segments covered) and rationale for decisions with regard to:
• Pretreatment
• Plowing
• Type and quantities of materials applied to road surface
• Segments of road covered
• Timing of start of action
• Timing of completion of action
• Description of road conditions</td></tr>
<tr><td rowspan="2">Crew comments</td><td>Crew perception of value and usefulness of information received (how it influenced their decisions):</td></tr>
<tr><td>Any other general comments?</td></tr>
<tr><td colspan="2">Other Event Information (for each separate event)</td></tr>
<tr><td rowspan="5">Initial and On-Going
Event Notification</td><td><u>From MDSS</u>:
• Time of first notice. Browsing? Auto Alert? What alert settings used?
• Content of notice/alert:
• Forecast start time?
• Forecast end time?
• Forecast type/magnitude?
• Different by each forecast point?</td></tr>
<tr><td><u>From MaineDOT</u>: (time of notification; information content)
• Augusta
• Radio room
• Crews on the road / storm patrol
• Timing and event magnitude reported by each source</td></tr>
<tr><td><u>From NHDOT</u>:
• Timing of notice
• Did NH call ME or visa-versa?
• Content of notice
• Forecast timing and magnitude of event</td></tr>
<tr><td><u>From other source(s)</u>:
• Timing
• Content
• Forecast details</td></tr>
<tr><td>Describe effect information had on decision making</td></tr>
<tr><td>Crew Deployment</td><td>Crew split (details on decision; rationale)</td></tr>
</table>

Information Type	Data to be Recorded
Resource Deployment	What trucks were assigned to the event?
	What materials were used?
Information Provision and Action Recommendations	What did MDSS recommend?
	Differences by MDSS forecast points?
	What did MaineDOT recommend crews do? Discuss rationale.
	How often and in what ways did MDSS provide information to MaineDOT decision making during event?
	Did MDSS help in defining the end of the event?
Perspective on the Event	Is there anything MaineDOT would have wanted to do differently?
	What role did MDSS play in decision making?
	How helpful was MDSS in decision making?
	What was decided or what actions were taken that would not have occurred without the MDSS?
	Did MaineDOT contact DTN meteorologist? If so, what was discussed? How did that influence decisions made?
	Describe the value, if any, of having multiple forecast points with MDSS:
	Discuss reliability of MDSS and ESS data and forecasts.
	Rank MaineDOT confidence in MDSS information *for this event.* 0 1 2 3 4 5 6 7 8 9 10 None Very Low Moderate High Total
	Describe how MaineDOT *would have handled event differently in absence of MDSS.*
Any Other Comments	Comments:

As it turned out, the crew met with their supervisor, and a call was scheduled with the evaluation team that included all the crew and their supervisor shortly after each event. In this way, they were able to recall the details of the event with agreement, and the recordings were helpful but not essential to the event reconstruction process.

Prior to the phone debriefing, the supervisor would provide the evaluation team with a copy of the MATS report that contained some of the data called for in Table 7. The data recording process was refined over the course of these debriefings, and the supervisor would take screen shots of the MDSS displays at various points in the course of a given storm event and share the information that had been provided during the debriefing. This facilitated the accuracy of the event reconstructions and helped document the uses and value of the MDSS information as it applied in each of these events.

Thus, each of the reconstructed events included a description of the event data recorded by MaineDOT, a sample of the forecasts and a list of all the alerts provided by the MDSS, a sample of observational data from the Portland Jetport ASOS, and a narrative reconstruction of the actions taken by MaineDOT and the rationale for those actions based on the telephone interviews. All of this information taken together led to an interpretation of evaluation findings, lessons learned and recommendations that are described in the following chapters of this report.

6 Findings and Lessons Learned

6.1 Introduction

Compared with typical winters in Maine, the winter of 2006-2007 was milder and there were fewer severe storm events. There were 21 recorded winter storm events between December 2006 and April 2007, and most of them produced less snow than would have been expected based on historical weather patterns. A total of 12 of these winter storm events were evaluated in detail, a process referred to in this report as event reconstruction. This approach to understanding how the MDSS was accessed and used to support maintenance decision making by the Scarborough crew was described previously in Section 5.2. This chapter discusses how MaineDOT used the MDSS in their storm management, presents findings based on these reconstructed events, and presents lessons that can be drawn from MaineDOT's experiences with their initial use of an MDSS.

6.2 The MDSS Role in Road Maintenance

6.2.1 Background

For each of the events examined during the winter of 2006-2007 in this evaluation, the Scarborough crew, with the support of MaineDOT management, sought to include the MDSS in their decision making in whatever ways they thought would be helpful. Initially they specified the alerts they wanted to receive for several forecast points along the test route (see Section 3.4 for details). In addition, the Scarborough supervisor and members of the crew learned how to access the MDSS on their computers, which they could do in the office, and in some cases at home as well. Also, the operations room in Augusta was set up with access to the MDSS on their office computer. Augusta primarily used the MDSS to provide the NWS radar image display and warnings (as opposed to monitoring weather and pavement conditions at specific forecast points across the state) so they could easily track storms as they approached and progressed across the State of Maine. They played a key role in notifying their regional maintenance crews, particularly during night time hours.

MaineDOT management and the Scarborough crew participated throughout this assessment with a very positive, supportive attitude and a commitment to work with the MDSS. At the initial meeting between MaineDOT representatives, the evaluation team, FHWA, and representatives of the MDSS vendor, the MDSS was discussed in detail. From that point on, it was largely a trial period in which the Scarborough crew attempted to apply the tool on a storm-by-storm basis and "test" out how it might be able to help them in their maintenance decision making. The vendor team made themselves readily available to MaineDOT by phone and e-mail for inquiries and consultation as needed to support this deployment. The vendor encouraged the Scarborough supervisor to contact their meteorologists at the beginning of every event for help interpreting the MDSS forecast output and as a way to better fine tune the decision guidance being offered.

6.2.2 Summary of Findings

This winter provided an opportunity for the Scarborough crew to experiment with the use of the MDSS. MaineDOT believes that deploying this system provided an important learning experience and valuable new information they formally lacked. Overall, they are quite positive about the future potential for an MDSS to support their winter maintenance operations. They acknowledge that they need to explore ways to modify their approach to and use of the MDSS to better take advantage of the benefits it offers. They also would like to see improvements in the MDSS tool to increase the accuracy of its forecasts, and they want to concurrently fine tune the set of treatment recommendations that they provided for use in the MDSS. The net benefit of the MDSS is difficult to assess in this initial application period. Over each of the observed storm events, the crew considered a combination of their real time observations of conditions on the road and input from a variety of weather information sources in addition to the treatment recommendations and related forecast information provided by the MDSS. Initially they were willing to "experiment" with the MDSS and implement its treatment recommendations as provided. Later they were inclined to review those recommendations and adjust their decisions based on all the other information that was available to them at the time.

This winter season was the first opportunity for the Scarborough crew of MaineDOT to try out the MDSS which had only been made available to them a few months earlier. The adoption of new technologies and new ways of making operational decisions involves changes and acceptance by crews and management that can take a relatively long period of time. It is reasonable to expect that the pace of internal organizational change, coupled with improvements to the MDSS tool, will lead to greater usage and success in future applications of such tools.

This section discusses a number of the findings derived from the reconstruction of the winter's storm events, along with additional explanation and interpretation. Each of the findings below includes discussion of the finding with regard to one or more of the objectives established for this case study evaluation.

- Assess the operational use of an MDSS by reconstructing each of the winter storm events and Maine DOT's management of those events.
- Identify institutional issues and implementation costs faced by MaineDOT in integrating an MDSS into their winter maintenance decision processes and how these issues were addressed.
- Identify effective strategies for deploying an MDSS.
- Assess how an MDSS supplements the suite of tools available to MaineDOT for making winter maintenance decisions.
- Assess the potential benefits that an MDSS could offer MaineDOT if it were utilized more comprehensively.
- Identify lessons learned from MaineDOT's experience using an MDSS.

Receiving too many alerts provided by the MDSS is of limited benefit and can be distracting. By the third recorded event MaineDOT had set up and subscribed to receive alerts at all four forecast points in the study area, resulting in numerous alerts being generated and received by the crew. In most of the events such a large volume of alerts was generated that the Scarborough crew found them to be overwhelming and at times distracting. In one storm event, for example, 87 alerts were generated. These alerts usually were triggered by the same weather front at all four forecast points in short succession (due to the relatively close proximity among the forecast points in the study area), that was found to be duplicative and not particularly useful. These alerts usually consisted of a mixture of forecasts (e.g., snow expected at 2:30 PM at Falmouth), observed conditions (e.g., snow observed at Falmouth), and NWS advisories and warnings. The crew indicated they would not go back to check on old messages when they showed up in a large batch or rapid succession. They noted a lot of variability in what these alerts were telling them about the timing and type of precipitation to expect over the course of a storm. That is, they felt that the alerts did not always provide consistent, actionable information.

The reconstruction of these events suggests that the use and value of the alerts varied across the events. The initial alerts were the most useful as they offered an early warning of an impending storm, and provided an initial forecast of the precipitation type and timing. A value of these alerts is to prompt the supervisor and crew to go to the MDSS on line and assess the more detailed information about the coming storm. It is this early information that provides guidance for deciding when to call in the crew and the storm conditions to anticipate as a basis for making pre-treatment decisions. Many of the alerts were not used, either because they arrived during the crew's "quiet period" at night, because the number of alerts seemed overwhelming, or because the information didn't appear to agree with the crew's observations.

Some of the Scarborough crew's storm management practices benefited more by using the MDSS than others. The routine of the crew remained very much as in prior winters, in which they accessed a variety of tools, including various weather forecasting systems, consulted as needed with their Augusta operations center and exchanged information, when appropriate, with NHDOT and neighboring crews. The prime MDSS component that offered pavement condition and temperature forecasts was of some value to the crew in practice and would likely have been of greater benefit with additional training in how to make best use of this information. The Scarborough crew noted that the pavement temperature forecasts provided by the MDSS were consistently close to the readings they obtained directly from the IR sensors on their trucks. This allowed them to develop some confidence in the pavement temperature forecast trends that were offered by the MDSS and consider that information in making their road treatment decisions. However, the crew entered into this winter season with only a limited understanding about how they could take advantage of the availability of a pavement temperature trend forecast to improve their treatment decisions. Their level of understanding, coupled with an inability of the MDSS to adjust treatment recommendations based on prior actions taken by the crew on the road (and hence an understanding of actual road surface conditions during the storm), limited the usefulness of this element of the MDSS.

The crew regularly consulted the MDSS ahead of each storm event, whether prompted by an alert or their knowledge from other sources that a storm was coming. When the supervisor arrived at the Scarborough shed, he would check the MDSS vendor's web site on his computer for the latest information and forecasts. The Augusta operations center also tracked the NWS radar images and forecasts via computer.

MaineDOT maintenance crews are very interested in having access to accurate forecasts of the type and amount of precipitation to expect before the start of a storm and the precipitation start time. This allows them to time pre-treatment, efficiently schedule their crews, and have consistent guidance regarding the type and amount of chemicals that will be most appropriate to apply to their pavement. They initially followed the MDSS treatment recommendation at the start of a storm closely. In some instances, they used less materials based on the MDSS recommendation than they would have otherwise, and said that worked well. However, they found in those instances that they usually needed to increase the subsequent treatment amounts to compensate for the lesser initial treatment. After some experimentation in the early storm events, they subsequently assessed a variety of weather information sources along with the MDSS, including private sector forecast services, television broadcasts of local news weather reports, and a network of weather information sharing with nearby crews and with sources in neighboring New Hampshire. Their decisions were then based on all these sources rather than simply following the MDSS recommended treatment.

The Scarborough crew also relied on night patrols and a weather observation station at the Portland Jetport that provided weather observation data. The closest ESS to the Scarborough crew was outside of the study area and therefore offered less useful observational data for decision making. Finally, their own crews on the road provided a constant source of input regarding prevailing conditions. It is within this context that the MDSS sought to offer enhanced road weather forecasting capabilities and decision guidance regarding treatment timing and choice of material types and amounts.

It is difficult to provide consistently accurate weather forecasts for the complex maritime climate in southern Maine. This case study offered an opportunity to test the MDSS under challenging weather and climate conditions. If it proved accurate, offered helpful information, and was easy to use, then the crew could be expected to rely on it more. In some event situations it provided good forecasts of either the start time or end time of the storm, or the precipitation type, or pavement temperature trends. In others it missed the mark by too wide a margin for it to be useful. The general consensus over the course of the winter was that the MDSS was better at forecasting the timing of the start of a storm than it was at forecasting the precipitation type, but this was quite variable across storms as well. Local geography coupled with a maritime climate and the confounding effects of ocean temperatures apparently made it very difficult for the MDSS to generate accurate forecasts of precipitation type. Two of the storm paths were over open water before coming on shore in southern Maine, resulting in a wetter precipitation pattern than the MDSS was forecasting. Often, when air temperatures hovered close to the freezing point, the MDSS would forecast snow but rain or freezing rain would actually occur.

It was evident that other weather services (other Internet weather information services, local radio and television stations) as well as the MDSS had limited success in forecasting the often tricky ocean effect weather events of the type that occurred in the study area. While most weather information service providers take input from NWS forecasts and other shared resources (e.g., radar, satellite images), mission critical (e.g., maritime, aviation, or MDSS) local forecasts usually require routine, and manual refinement by in-house meteorologists employed by the respective weather information providers. MDSS meteorologists may lack the advantage of on site, real-time feedback and knowledge of the local area to make timely and effective adjustments, especially when complicated geographic and micro-climatic scenarios are involved. This is a common challenge for all weather service providers and is not unique to an MDSS. Accurate local forecasts are absolutely essential for the provision of MDSS services. One limitation in this study was the lack of any ESS in the immediate study area, which, as demonstrated in the federal MDSS prototype, could be used to provide real-time atmospheric and pavement observations in support of “forward correction” of the forecasts.

The Scarborough crew primarily relied on multiple sources of weather information, including the MDSS, their local experience, and crew observations on the road to make treatment decisions during a storm. During the event reconstruction interviews after a storm event, the crew emphasized how they really didn't have the time in the middle of an event to consult an MDSS or any of their other standard weather forecast tools because they were so busy "fighting the storm." In addition, while the crew is out on the road dealing with the storm effects, they base their treatment and related operational decisions primarily on their observations of conditions and how traffic is responding. For example, they can observe how the materials on the pavement surface are being deflected by vehicle tires to judge the effectiveness of their treatments and the next most appropriate treatment strategies. They are much more inclined to rely on their years of experience and real-time observations than on a forecasting tool that is not closely connected with the actual conditions.

The Scarborough crew tended to mostly apply greater material amounts to the pavement than the MDSS recommended. A central purpose of an MDSS is to offer the road maintenance crew treatment recommendations that are based on forecasted weather and pavement conditions and updated as actual conditions change. An MDSS ideally offers an alternative to ad hoc decision making that may be based substantially on anecdotal information. A scientifically grounded treatment guidance system should offer benefits in terms of a more efficient use of costly materials, labor and equipment resources, assuming the forecast data are accurate. It has been a long-standing practice of the Scarborough crews to apply their chemical treatments conservatively; that is, they typically apply a higher amount than might be recommended by an MDSS, especially in the first treatment, because they want to be sure that adverse conditions don't get ahead of them. They would rather not find themselves having to play "catch up" in subsequent treatments. They believe that if the initial treatment(s) prove to be inadequate, the later treatments will need to be substantially greater to recover LOS, likely resulting in higher resource usage over the course of the storm. This conservative approach suggests that there is an opportunity for a decision support system that can accurately and consistently guide the best possible treatment decisions, thereby offering the potential for resource and cost savings.

In selected storm events the Scarborough crew was able to use the MDSS forecast to make a decision not to pretreat the pavement. In some others they were able to use less materials based on the MDSS forecast. It is difficult however to assess the amount of savings over an entire event attributable to the MDSS because often the crew reported that their subsequent treatments were increased over what they might otherwise have done in the absence of an MDSS. It is also difficult to separate out the influence of the MDSS from all the other forecast and observational tools that they used.

The MDSS typically recommended less material than the crew was comfortable applying under a given set of conditions. These recommendations were arrived at as a function of the standard treatment protocols provided by MaineDOT and placed in the MDSS, and the MDSS forecasts. As noted earlier, the crew followed several lower-bound treatment recommendations, which actually performed well under the conditions as they turned out. The crews later tended to apply significantly more than the MDSS recommended amounts in subsequent treatment decisions. In their experience with almost all of these events, their decision was supported both by the experiences of other crews in the area and by the demonstrated success on the road of the chemicals applied at those higher levels. However, since the crew didn't consistently follow the MDSS recommended treatment amounts, it is not possible to fully assess either the efficacy of the recommended treatments nor the benefits that would have accrued had they been closely followed.

The resolution of the weather forecasts was not high enough to allow the MDSS to differentiate conditions across the set of forecast points along the relatively short distances covered in this study area. One of the expectations from this assessment was that MaineDOT would be able to use the multiple forecast points along the study route to identify sufficient differences in forecast weather effects (timing, precipitation amount, and air and pavement temperature trends) to be able to apply differential treatment regimes along the route. Such an approach also would offer the potential to save in material usage and costs by varying the level of treatment by locale. This did not turn out to be the case. First, the sets of alerts provided for each of the forecast points tended to provide identical or very similar information. Second, the forecasting was not precise enough to allow for point forecasts that could accurately differentiate conditions at these different locations. An illustrative example was provided by one of the reconstructed storm events in which observed snow fall was much more pronounced in the southern end of the route; however, MDSS forecasts for the two extreme south and north forecast points were unable to capture these differences sufficiently to support different maintenance treatment decision making by the Scarborough crew.

Viewing their experience with the MDSS as a whole, MaineDOT found benefits in the approach and potential for the future. While the Scarborough crew did not find the MDSS to be sufficiently accurate and consistent enough to rely on it as a tactical tool for their treatment decision making during the storm, they saw the introduction of this tool as a valuable first step toward integrating route-specific weather and pavement condition information on a GIS platform. They felt that this preliminary deployment provided an experience base upon which they can learn to enhance their use of this tool to derive increased benefits in the future. They plan to make modifications to the alert structure and precipitation timer, and are considering how they might modify the treatment recommendations imbedded in the MDSS to better address their state's needs by maintenance shed. They want to work with the MDSS vendor to enhance their use of the pavement temperature and bridge frost information components. This past season was viewed as a valuable learning experience, and MaineDOT is looking to the future to enhance their management of storm events through the better use of an MDSS.

6.3 Summary of MDSS Benefits

MaineDOT has had a proactive approach to maintenance operations for quite a few years. They prepare for a storm event by having their trucks already loaded and ready to go, they have their night patrol, their operations center providing a statewide perspective, and their crews on call or ready to go when they know a storm is coming. The MDSS supplemented this readiness in the following ways.

- It offered useful features not previously accessible to MaineDOT. These included a GIS radar and NWS weather forecasting platform that their operations center could use to track storm events across the state. This provided enhanced notification capability for the various maintenance sheds.

- It provided a consolidated set of treatment recommendations and made them easily accessible to the crews to support their pavement treatment decisions. The MDSS framework allows a DOT to customize these treatment recommendations to the particular needs of their maintenance shed locations. MaineDOT relies heavily on their crews' treatment judgments because there are so many variables involved, such as time of day, day of week, traffic levels, air and pavement temperatures, precipitation type and amount, and the effects of prior treatments.
- The GIS platform allows inclusion of RWIS/ESS, ASOS and other observational data to be represented and assessed. They liked the ability to be able to overlay pavement temperatures on a road map. MaineDOT is interested in including data for their state and adjacent states in this way.
- New data were available on bridge frost potential, pavement temperature trend forecasts, and wind and blowing snow potential.
- MaineDOT's maintenance strategy is to first look to their crews and learn from them what is happening out on the road, then from there go to forecasts of what is expected to happen in the future.
- MaineDOT's treatment decisions rely significantly on their crews' observations of pavement temperature. The MDSS provided the ability to extend those observations with trend forecasts.
- MaineDOT saw potential for improving the alert notification provided by the MDSS that could help them in storm preparedness.
- MaineDOT believes the MDSS offers a very useful training tool to help all DOT maintenance crews throughout the state operate on a par with their best crews.

MaineDOT viewed the MDSS in this first season's experience as a planning tool to help them identify precipitation type and timing as a storm is approaching. They did not tend to view it or use is as a tactical tool to manage their activities during the storm event.

The Scarborough crew found that their traditional sources of weather forecast information were at least as accurate as those provided by the MDSS. Although the crew reported that the MDSS did not change most of their decisions from what they would have been in the absence of the MDSS, they did make a concerted effort to examine and explore ways to use MDSS information for every event.

The MaineDOT crews who used the MDSS came to better appreciate the potential of this kind of decision support tool, and they appreciate more than at the start how an MDSS could offer them benefits. MaineDOT believes they have derived benefits from having a weather forecasting tool that provides a set of capabilities they have not had available previously. As the MDSS is refined and further deployed, trust and confidence in its use can be expected to increase. The MDSS tool as deployed this first season in Maine has provided benefits, and with further refinement, user training, and consistent application it can be expected to offer greater accuracy, consistency and ability to differentiate variable conditions across Maine's complex geography and local climates. The benefits it has provided constitute a platform upon which MaineDOT can build over upcoming winter seasons.

6.4 Lessons Learned for State DOTs

MaineDOT worked with the initial MDSS deployment over the 2006-2007 winter season in a single interstate corridor around the Portland, ME metropolitan area. The MaineDOT Scarborough crew enthusiastically took on the challenge of incorporating the MDSS into their existing suite of weather support tools. While they had decades of experience dealing with winter storms, they had essentially no training or advance preparation for how to use an MDSS. The initiation of this assessment just as the winter season was getting under way meant that all the stakeholders in this process were learning together as the storms were upon them how an MDSS might affect the crews' maintenance and road treatment decisions.

This section summarizes a number of lessons that were learned in the course of three months of experience with the MDSS.

An MDSS that offers accurate and consistent forecasts and treatment recommendations is more likely to engender trust and confidence in the users.

A complete MDSS is more than a weather forecasting tool. It is a decision support tool that seeks to guide the timing, type, and amount of materials a DOT will apply to their pavement throughout a storm based on accurate forecasting of weather and pavement conditions. In order for the MDSS to offer full benefits, maintenance crews need to have the confidence to follow the MDSS treatment recommendations. In practice, this means that the crews first need to be willing to apply the recommended treatment type, amount and timing, then, after giving it a fair trial over successive storm events, they can evaluate the performance of the MDSS. If it proves to be effective and offers measurable benefits, then the crews are much more likely to build trust in the tool and use it consistently. If the MDSS forecasts and recommendations appear off the mark, compared to the other available tools or to the crew's experience, then the MDSS recommendations are less likely to be consistently followed.

MaineDOT experienced an unusually mild winter, which presented its own set of challenges for weather forecasting tools. While there was considerable variability in type of precipitation, temperature, and wind conditions, the weather events typically hovered around the border between rain and snow. This made it quite difficult for the MDSS, and the other available weather forecasting tools, to forecast precipitation type, amount and timing with accuracy. Any such tool, including an MDSS, must seek to demonstrate accuracy and consistency across all the precipitation types that a DOT can expect to experience. Also, the DOT agencies need to ensure that the treatment recommendations offered by the MDSS are appropriately customized for their environment and operations. Then they can evaluate the benefits of modifying their standard maintenance practices to reduce costs associated with labor, materials and equipment usage. However, user trust in the basic functions of the tool must evolve before the more advanced capabilities and potential can be fully realized.

Provide training to maintenance crews before MDSS introduction, and offer additional training and support thereafter in the use of an MDSS to derive full benefits to improve maintenance decision making.

The pathways to benefits presented earlier in this report described many different ways that an MDSS could lead to decision making that could either reduce operational costs, increase benefits, or accomplish both. This assessment made it clear that in order to operate along these pathways, the users of the MDSS need to fully understand how it works, how best to apply it in support of decision making, and how to interpret the information it offers. To accomplish this takes more than enthusiasm and support for the use of the MDSS; it also takes time to learn, time to accept news ways of operating with the MDSS, and time to develop the level of trust in the MDSS to fully accept it into regular operational practice.

The MDSS vendor can offer active support to the maintenance crew that is using the MDSS to explain its capabilities, answer questions that arise, and suggest effective ways to take best advantage of its capabilities. This is the role that was played by the MDSS vendor in working with MaineDOT. The more active this relationship between the MDSS vendor and the DOT, the more effective the MDSS will be in supporting the DOT's maintenance operations. The MDSS vendor offered MaineDOT the services of their meteorological staff and encouraged the Scarborough crew to call before every storm event to obtain further guidance and interpretation of the forecasts that were being provided by the MDSS. In this sense, the crew can play a role in improving the quality and effectiveness of these MDSS forecasts by helping the vendor fine tune the forecasts based on the observations, experience and interpretations of the local crews. In addition, the crew needs to be willing to act on the recommendations of the MDSS in order to realize the potential benefits it offers.

DOTs should expect that it will take time for their management and maintenance crews to adopt and accept an MDSS into their standard operations.

Organizational change of any significance is usually slow to occur because it is human nature to hold on to what has worked well in the past and to resist change that presents uncertainty and the risk of failure. A basic ingredient for organizational change is strong leadership backing the change and a willingness on the part of the organization's personnel to try new ways of performing their jobs. MaineDOT had each of these prerequisites for change in their favor. At every level of the DOT, there was strong support for the adoption of an MDSS. Nevertheless, a single winter season, with no advance preparation or training, is not conducive to adoption and acceptance of such a new and different way of operational decision making. As noted in several of the accompanying lessons, adoption and acceptance depend on forecast accuracy in practice, crew training in how to best make use of what the MDSS has to offer, and an MDSS that is closely customized to the conditions where it is being applied.

Configure MDSS treatment recommendations in close consultation with the DOT, and customize them to fit the conditions, needs and practices of the crews in the district where the MDSS is to be used.

In providing a treatment protocol for incorporation into an MDSS, MaineDOT decided to select an average set of treatment guidelines under a set of weather and pavement temperature ranges that could apply across the state. In Maine there are variations in winter weather patterns and treatment strategies across the state. The Scarborough region tends to experience less harsh winters than other parts of Maine and they also have a heavily urbanized portion of the state. The Scarborough crew tends to apply more chemicals under a given set of weather and pavement conditions than the state average treatments that were configured in the MDSS. This predisposition to heavily treat the roads (for example, to apply higher amounts initially to assure effectiveness and reduce the need to "catch up" with subsequent heavy treatments) caused the Scarborough crew to exceed the initial recommended treatment levels on a fairly consistent basis. The MDSS derived its treatment recommendations primarily from forecasts of air and pavement temperature that were linked with MaineDOT's "average" guidelines that had been incorporated into the MDSS. This resulted in fairly consistently under-recommending the amount of chemicals needed in the judgment and experience of the Scarborough crew.

While a possible strategy would be to tailor the treatment protocols in the MDSS to the prevailing conditions where the MDSS is going to be applied, the DOT needs to be cautious not to negate the potential benefits of more finely tuned treatment recommendations from the MDSS compared with the DOT's standard operating procedure. A better approach would be to work closely with the MDSS vendor to implement a protocol of treatment recommendations that offer the potential for effectiveness and cost savings, consistent with the DOT's standards for road maintenance. Arriving at an optimal configuration may be an iterative process, with the DOT and the vendor reflecting on the performance of the MDSS after trial periods. The DOT may discover in this process that their existing treatment protocols can be modified to provide greater efficiencies and savings.

DOTs should select the alert topics and alert timing that will be most helpful in making their road treatment decisions while avoiding generating too many alerts that become more distracting than helpful.

The MDSS offered MaineDOT a wide variety of possible alerts covering all the possible event types for each forecast point created for the study region. The more alert topics, forecast points for which alerts are requested, and frequency with which alerts are generated, the more total alerts that will be sent and received. Across the events reviewed in this evaluation for which alerts were provided by the MDSS, an average of 50 alerts per event and about 3.3 alerts per hour were generated based on the criteria specified by MaineDOT. In the judgment of the Scarborough crew at the end of the winter season, this was such a large number of alerts that they found themselves disregarding many of them and at some points finding them distracting. Later in the winter, the supervisor elected to cut back on the number of alerts and stopped providing them to every crew member.

The number of alerts has to strike a balance between too few to provide timely and useful warnings, and too many such that they become a distraction and end up being ignored. In part due to the small geographic area covered by this study, alerts for each of the designated forecast points proved to not be necessary. Alerts issued for different forecast points are only helpful when the information at each forecast point is significantly different from the others. Receiving multiple alerts that all say the same thing is less helpful. The DOT will need to assess their experiences with the MDSS alerts and fine tune them to best meet their needs.

MaineDOT's experience suggests that it would be helpful to configure forecast points that are outside the maintenance area along storm paths to offer improved advance warning of storms. In this way alerts can be generated based on weather conditions that are known to be likely to precede the conditions that will be experienced by the maintenance crews. MaineDOT's traditional strategy for alerting crews has been to communicate with NHDOT and with other crews adjacent to their crew shed area to get advanced warnings of precipitation type, intensity and timing. The MDSS can effectively supplement these warning strategies by configuring alerts efficiently.

Maine DOT learned that alerts do not need to be continually issued over time when the information content has not changed significantly. Issuing alerts only when conditions have changed is one way to reduce their numbers and maintain their salience to maintenance operations. Alert wording should be short and clear, with the main objective of alerting the operator to consult the MDSS for more detailed information. Alerts serve as a warning of an impending storm event and should prompt the DOT to actively monitor the MDSS as the storm progresses. Alerts need to be configured for users according to the times of day when the crews are prepared to receive them and make best use of them. When a crew member is off duty or asleep, the alert can be directed to a supervisor or radio operator who is on duty and can act on them immediately. This is how MaineDOT provided 24/7 coverage.

MaineDOT's experience with the MDSS alerts illustrates the value of evaluating alert information in conjunction with other sources of data on impending or current weather events in order to derive the best information from both forecast and observational data in support of decision making.

Provide a mechanism in MDSS treatment recommendations to incorporate the effectiveness of prior treatments, along with observational data, in order to better adjust forward-looking recommendations.

The MDSS used by MaineDOT was of most value at the front end of a storm event and less so during the event, partly because of its lack of ability to factor current conditions into its recommendations, partly because data on crew actions and resulting road conditions were not being fed back into the MDSS, and partly because the crew felt they were too busy "fighting the storm" to pay closer attention to the MDSS during the storm. The Scarborough crew evaluated the MDSS before every storm event, along with their other sources of road weather information, and made their decisions whether to pre-treat the road and what type and amount of chemicals to apply. While they didn't necessarily follow verbatim the recommendation of the MDSS, they incorporated it into their decision making. Other than for pre-treatment before a storm began, much of the treatment decision making that occurred during the storm was made by truck operators on the road under the stress and pressures of "fighting the storm."

Maintenance crews need concise, timely information mainly about variations in conditions across their region of responsibility and forecasts of changes in the timing and type of precipitation, air and pavement temperature trends, and guidance for optimal treatment types and amounts based in part on actions they already have taken. The supervisors as well were often not at their desks in front of their computers during storm events to monitor the MDSS. As a result, the Scarborough crew consistently consulted the MDSS before the event but not regularly during the event. DOTs can enhance the potential accuracy and benefit of an MDSS by making RWIS/ESS data available for the geographic areas to be covered by the MDSS forecasts and treatment recommendations.

State DOTs can leverage the potential value of an MDSS deployment by offering it initially to one or more of their more progressive crews.

MaineDOT viewed this experience with an MDSS as a way to show their crews statewide that there are potential benefits and advantages to using an MDSS in support of winter maintenance operations. The more advanced crews can then serve as an example as well as offering training to other crews.

An MDSS is a very different and more complex technology compared with many of the systems used throughout Maine and in other states. Maintenance personnel who are uncomfortable with computers and related technologies may be reluctant to accept and work with an MDSS initially. MaineDOT offered the MDSS to a number of their maintenance crews and selected the Scarborough crew for this assessment project based in part on their enthusiasm and willingness to work with the MDSS throughout the winter season.

An MDSS should be viewed as a valuable tool in a DOT's winter maintenance operations tool box, offering the benefits of an integrated GIS platform and significant educational value.

MaineDOT routinely accesses a variety of weather forecasting and informational sources that include local weather station broadcasts, private weather services, local ASOS, and regular communications with NHDOT. They access data from five RWIS/ESS located throughout the state. This past winter season they also had access to the MDSS vendor's staff of meteorologists to provide interpretative guidance that formerly was obtained through a contract meteorologist.

MaineDOT found that the MDSS supplemented these resources in some important ways. First, the MDSS added capabilities that they previously didn't have from their other tools. These included pavement temperature forecast trends, bridge and road surface frost forecasts, and a tool that could provide pavement treatment recommendations based on an analysis of multiple weather parameters. Second, the MDSS offered an integrated platform for the display and analysis of NWS forecasts in a user friendly GIS format. This capability was particularly valuable for use in their Augusta operations center where they were able to track storms across the entire state and notify their crews selectively and strategically in advance of severe weather. Third, the MDSS as used in this first winter season offered significant educational value for the crews that used it. Crews became much more aware of the variety of valuable weather information that is now becoming available and how to interpret that information in the context of their existing tools and extensive on-the-road experience fighting storms. This experience with the MDSS has positioned these crews to be able to more effectively utilize MDSS capabilities in the future.

The pavement temperature forecast module is an example of an important element in the MDSS that must be well understood by a DOT to provide benefits. The MaineDOT Scarborough crew regularly tracked pavement temperature with their IR pavement sensors on their trucks and used that information in making their treatment decisions. What was new in this study was the availability of pavement temperature trend forecasts that could help the crews anticipate whether the pavement was expected to warm up, cool down, or stay about the same for several hours into the future. The evaluation team prepared graphic representations of these trends, coupled with ASOS readings of air temperature from the Portland Jetport to illustrate what the MDSS data were showing in each storm event (see Figure 6 for an example). Also, Table 1 on MDSS Pathways to Benefits outlines some of the key decision pathways associated with pavement temperature trend forecasts provided by an MDSS. A DOT can use this information from an MDSS to help them decide where to treat, when to start treatment, what types and amounts of materials to use, whether pretreatment is necessary, and the likelihood of road or bridge frost occurring.

7 Conclusions and Recommendations

The MDSS deployed by MaineDOT in the winter of 2006-2007 offered the DOT and the Scarborough road maintenance crew a useful winter storm planning tool. In its current configuration, it is primarily a weather forecasting tool. The needs of state DOT's varies widely, and many that have not yet decided to deploy an MDSS may want to move is this direction in a more step-wise fashion without committing to a more costly, fully evolved MDSS system initially. There is benefit in offering a relatively inexpensive tool focused on helping maintenance operators better forecast the timing and type of precipitation at the beginning of a storm event. The MDSS offered a tool that helped MaineDOT integrate a variety of critical weather data into a useful GIS platform. These capabilities alone meet the most frequently expressed needs of DOTs that want a tool that can help them better time their pre-treatment decisions and determine the correct materials for the conditions they are going to face at the front end of a storm. They want to know start time, precipitation type, anticipated amount of precipitation, and duration. MaineDOT acknowledged that even when they had access to a meteorologist on contract to provide storm forecasts, they had a hard time predicting these key attributes of a storm. An MDSS that could improve their ability to only do that would be very valuable, and may be all that many state DOTs want or need.

MaineDOT found their experience overall with the MDSS to be a beneficial one. However, it was also apparent from the event reconstruction and interviews with the crews that the influence of this tool on their maintenance and treatment decisions could have been greater had the crews perceived a greater degree of accuracy, reliability and consistency in the forecasts and treatment recommendations provided. FHWA should encourage state DOTs to customize the treatment recommendations imbedded in the MDSS to fit their climatic, geographic, and operational needs. They also should encourage MDSS vendors to work closely with state DOTs, understand the range of different needs among the states, refine their MDSS based on the experiences of state DOTs, and make improvements where they offer clear value to users.

The FHWA is seeking to extend the benefits of the winter MDSS as a year round tool that can assist state DOTs through enhanced weather awareness with such activities as road striping, herbicide spraying, and other non-winter road maintenance activities. A focused, relatively non-complex and inexpensive MDSS tool of the type used by MaineDOT this past winter season may offer a suitable platform upon which to develop these kinds of decision support tools for more extended uses.

The transportation community, including federal and state agencies, should continue to support the development of several different MDSS systems that offer state DOTs a choice of capabilities, functionality, and cost. This kind of environment helps encourage innovation and attention to meeting a range of different needs in different parts of the country. The MDSS deployed by MaineDOT raised awareness throughout the state of the value and potential of a tool that could supplement their existing weather forecasting and management tools with a set of capabilities they didn't have previously. Transportation agencies also can support training to capitalize on this growing awareness and encourage wider use of MDSS tools to help improve overall transportation safety, mobility, and productivity.

Appendix A

MaineDOT Treatment Recommendations

Table A. MaineDOT Treatment Recommendations

Treat #	PAVEMENT TEMPERATURE RANGE AND TREND	INITIAL OPERATION				SUBSEQUENT OPERATIONS			COMMENTS
		Pavement surface at time of initial operation	Maintenance Action	Chemical Application		Maintenance Action	Chemical Application		
				Liquid Pre-Wet Gals/Ton	Rock Salt Lbs/lm		Liquid Pre-Wet Gals/Ton	Rock Salt Lbs/lm	
1	**Above 32°F** steady or rising	Wet, slush, or light snow cover	Plow as needed and monitor pavement temps.	Salt Brine 10 gals/tn	0-150	Plow as needed and monitor pavement temps	Salt Brine	0-150	1) Monitor pavement temperature closely for drops toward (32°F) and below 2) Treat icy patches if needed with Rock Salt at (150 lb/lane-mi); plow if needed
2	**28-32 °F**	Wet, slush, or light snow cover	Plow as needed; reapply solid pre- wetted chemical when needed	Salt Brine 10 gals/tn	150-250	Plow as needed; reapply solid pre- wetted chemical when needed	Salt Brine	100-200	1) Applications will need to be more frequent at lower temperatures and higher snowfall rates
3	**20 to 28°F**	Wet, slush, or light snow cover	Plow as needed; reapply solid pre- wetted chemical when needed	Salt Brine, $MgCl_2$ $CaCl_2$ 10 gals/tn	250-350	Plow as needed; reapply solid pre- wetted chemical when needed	Salt Brine	200-300	1) Applications will need to be more frequent at lower temperatures and higher snowfall rates
4	**15 to 20°F**	Wet, slush, or light snow cover	Plow as needed; reapply solid pre- wetted chemical when needed	$MgCl_2$ $CaCl_2$ 10 gals/tn	350-450	Plow as needed; reapply prewetted solid chemical when needed	$MgCl_2$ $CaCl_2$ 10 gals/tn	300-400	1) Applications will need to be more frequent at lower temperatures and higher snowfall rates
5	**Below 15°F** steady or falling	Dry or light snow cover	Plow as needed			Plow as needed			1) It is not recommended that chemicals be applied in this temperature range 2) Abrasives can be applied to enhance traction 3) On higher speed corridors, if glazing occurs and sand will not stay in travel lanes, higher applications of rock salt may need to be applied with consent from Region Management.

Reference standard notes.

CHEMICAL APPLICATIONS. (1) If snow is blowing off the roadway and glazing or pack is not occurring, do not apply materials. (2) Time initial and subsequent chemical applications to *prevent* deteriorating conditions or development of packed and bonded snow. (3) Apply chemical ahead of traffic rush periods occurring during storm. (4) Higher volume corridors will often require an additional 50 lbs per lane mile above recommended amounts. (5) Snowfall greater than 1" per hour will often require an additional 50 lbs per lane mile above recommended amounts.
PLOWING. If needed, *plow before chemical applications* so that excess snow, slush, or ice is removed and pavement is wet, slushy, or lightly snow covered when treated.
TEMPERATURE TRENDS: If temperature trend is rising, use lower end of application range and conversely, if temperature trend is dropping use higher end of application range.
PRE-WETTING: If salt brine is not available, liquid calcium or magnesium chloride may be used if bounce and scatter will be a problem, i.e. conditions not wet enough.
FROST AND BLACK ICE: If frost or black ice is forecast and pavement temps will be above 20 degrees F, pre-treat with salt brine at 50 -60 gals per lane mile on designated corridors. Areas not designated for pre-treatment should apply as necessary at a rate of 150-250 lbs per lane mile.
FREEZING RAIN/SLEET: Freezing rain and sleet will dilute treatments sooner and may require more frequent re-application.

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