MDSS—the U.S. Success Story

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ABSTRACT

The purpose of this paper is to capture the current state of development of the Federal Highway Administration (FHWA) Maintenance Decision Support Systems (MDSS), deployment of MDSS by vendors and the Pooled Fund Study (PFS), document the acceptance and successes in the winter maintenance community, identify research and development issues that need to be worked, and pose a series of actions that need to be taken towards developing and implementing other weather-responsive transportation decision support systems. The paper will explore the original need for developing the MDSS, explain the role and importance of the multi-disciplinary stakeholder process in bringing together state-of-the-art weather forecasting techniques with computerized winter maintenance practices for treatment recommendations, and report successes in deploying MDSS first in the prairie states during the winters from 2003 through 2007 and then in the more challenging weather climates found in the mountainous regions of Colorado in 2005-2007.

The paper will also discuss processes underway for obtaining input from experts in the field of maintenance outside of snow and ice control to assist in defining the capabilities that should be delivered in a more comprehensive maintenance decision support system. It is envisioned that other areas such as construction management and traffic management will leverage the lessons learned and the technologies generated from the development of the FHWA MDSS to develop their Operational Decision Support Systems. The paper will explore the benefits of using road weather management strategies to mitigate impacts of adverse weather in these non-maintenance operational areas.

The MDSS program development process has been an extraordinary success. The multi-disciplinary stakeholder group has stayed together for more than seven years. Each year attendance and interest at the annual meeting continues to grow. The term MDSS is recognized internationally as weather and surface transportation integration and decision support. The American Association of State Highway and Transportation Officials (AASHTO) Technology Implementation Group (TIG) evaluated and determined that the MDSS project is a market ready technology and innovation. Currently, three value added meteorological services vendors offer MDSS and MDSS-type services in their product lines. Boschung, LLC, is developing an MDSS for the European market that is based on the FHWA MDSS.

TEXT

Background

During the past 15 years, research has made great strides in providing new strategies, equipment and materials for improving the winter maintenance and safety of highway transportation facilities. The Strategic Highway Research Program (SHRP) began the process with major investigative works on 1) Road Weather Information Systems (RWIS) and 2) Anti-icing (AI) Operations [references 1 and 2]. An International Winter Maintenance Technology and Practices Scanning Tour program followed the sunset of SHRP in 1994 [reference 3]. The winter maintenance scan of operations in Japan, Germany and Austria provided new knowledge about how other countries were utilizing RWIS, advanced material applications, and improved equipment design. After the completion of SHRP and the International Winter Technology Scanning Tour a "Lead States" program was put in place to help accelerate the implementation of RWIS and AI.

At the conclusion of the Lead States program, it became apparent that in spite of all of the benefits that RWIS and AI provided, there were opportunities for improvement. While RWIS was a good information source, it was not being used by much of the maintenance community. Where it was being utilized, it did not totally meet the decision support needs of maintenance managers. In an effort to build on the RWIS/AI research and to assist the decision maker, the FHWA conducted additional RWIS/AI field evaluations in Test and Evaluation Project TE-28, and developed a *Manual of Practice for an Effective Anti-icing Program: A Guide for Highway Winter Maintenance Personnel* [Reference 4]. This manual distilled the results of the field tests into eight winter storm scenarios and put them into eight tables for easy use in guiding the decision making process.

Then in 1999, FHWA and the US Department of Commerce, Office of the Federal Coordinator for Meteorology (OFCM) took bold steps to involve both groups of stakeholders to gain a greater perspective of how both disciplines could work together to reduce the negative impact of adverse weather on the surface transportation system. FHWA funded the Surface Transportation Weather Decision Support Requirements (STWDSR) activity in an effort to better understand the decision making needs of today's maintenance managers. Simultaneously, the OFCM began a requirements gathering process called Weather Information for Surface Transportation (WIST). Stakeholder meetings for these efforts brought the winter maintenance community, members of the weather community and interested parties from academia and the private sector together to gain greater perspective on the needs of the surface transportation community [Reference 5].

Among the outcomes from these stakeholder meetings was the need for the development of a Maintenance Decision Support System (MDSS) that would integrate state-of-the-art weather forecasting techniques with computerized winter maintenance practices that would build on the TE-28 treatment recommendations. Designing these complex computer algorithms required the creation of a multi-disciplinary stakeholder group made up of end users from the maintenance community and professionals from the entire weather enterprise [Reference 6]. The stakeholder group grew into a varied mix of winter maintenance managers from 40 State DOTs, the District of Columbia and six local transportation agencies and international stakeholders. There were also meteorologists from several national research laboratories, universities and private sector companies. This group has persevered for seven years providing guidance on the evolution of the federal prototype's graphical user interface, expertise on customizations needed for the treatment recommendations module and feedback each year on the development of the federal MDSS prototype.

Development and Deployment Status

FHWA MDSS

The first FHWA prototype MDSS was demonstrated and evaluated in central Iowa in 2002 and was first used in a field operational test over two winter seasons. Three maintenance garages participated in the demonstration. These were West Des Moines, North Des Moines and Ames.

As one might expect there were some start up problems and recognition that aspects of roadway weather forecasting were pushing the state-of-the-science of what was possible. However, after integrating lessons-learned from each winter, the performance of the prototype improved each year. Based on experience and user feedback and the introduction of new research, new FHWA MDSS Releases were developed and field demonstrated annually. Special emphasis was given to the weather forecasting component of the system to improve precipitation and short-term forecasts. The ensemble modeling system (which utilizes weather forecasts from numerous models) and the data fusion engine, the road weather forecast system (RWFS) were redesigned to take advantage of higher temporal resolution (hourly) model forecasts. A forward error correction technique was developed to nudge the initial several hours of forecasts closer to the observed field data. The method used to initialize the road temperature model was changed to utilize actual data from the RWIS rather than relying on model-derived estimates [Reference 8]. An algorithm for characterizing the features of the entire winter storm was developed for the Rules of Practice module. Also, application treatment recommendations were calculated by determining the optimal amount of chemical needed to protect from refreeze based on the chemical's eutectic properties, forecasted precipitation rate and type, road temperatures, winds and expected dilution from traffic and runoff. The display was upgraded to include alerts for blowing snow and bridge frost occurrence.

In Iowa, during the second winter evaluation, since most of the startup problems had been worked out during the initial season, the implementation went well with several of the recommended treatments being applied without any modifications and proved to be optimal solutions while the other recommended treatments needed only minor modifications. Any MDSS recommendations that were not consistent with experienced supervisors recommendations could be traced to serious errors in the road weather forecast.

The third year of field demonstrations was held during the winter of 2004-2005 in central Colorado. This move provided new challenges since the domain of the MDSS included both urban areas around metro Denver as well as complex mountainous terrain to the west of Denver. The demonstration in Colorado, however, did not have as good an outcome. As in the Iowa demonstration, the RWFS was configured to utilize and integrate ten different forecast modules in the ensemble modeling system. In the complex Colorado terrain there were large spreads between the models making it very difficult to tune to a best model.

Significant improvements have been made to the RWFS since the third year demonstration. The National Center for Atmospheric Research (NCAR) developed a new statistical method to make the RWFS more responsive to rapid changes and extreme events. NCAR also developed specific tuning for the 2006-2007 winter demonstration for the City of Denver and for the E-470 Public Highway Authority which operates a toll road around the eastern perimeter of Denver. Changes included modifying model weighting schemes and incorporating higher resolutions. The Probability of Precipitation threshold to declare precipitation was lowered from 25% to 20% to increase sensitivity. These changes greatly improved the forecasting quality.

Pooled Fund MDSS

In 2003, six state DOTs, led by the South Dakota DOT, formed a Pooled Fund Study (PFS) using the FHWA prototype MDSS as its foundation. Using State Planning and Research (SP&R) funds, along with minimal funding from

FHWA, the PFS contracted with Meridian Environmental Technology to do the development and integration. The PFS currently consists of ten state DOTs, California, Colorado, Iowa, Indiana, Kansas, Minnesota, New Hampshire, North Dakota, South Dakota and Wyoming. The PFS MDSS plans on transitioning from a research and development phase to operational deployment during the winter of 2007-2008.

DTN/Meteorlogix WeatherSentry MDSS

DTN/Meteorlogix leveraged the FHWA prototype MDSS capabilities and created a web-based MDSS tool that complemented their WeatherSentry product. During its initial season, winter of 2005-2006, ten states (Idaho, Iowa, Maine, Michigan, Missouri, Nebraska, Nevada, New York, Ohio, and Wisconsin) and the New York State Thruway Authority evaluated this new service. During the second season, winter of 2006-2007, the WeatherSentry MDSS was being used by eleven states and 75 local agencies.

Other MDSS Developments

Surface Systems Inc (SSI) developed a less complex MDSS solution partially based on the FHWA prototype MDSS. They marketed Storm Logistics in 2006 to thirty customers with good results. SSI sold their forecasting division and no longer markets MDSS.

Boschung, LLC, is developing an MDSS based on the FHWA prototype MDSS. ASFiNAG, the company responsible for snow and ice control on the major roads in Austria, is in the process of deploying Boschung's version of MDSS.

Future Operational Decision Support Systems

The use and acceptance of MDSS to support multi-faceted decision making in winter maintenance operations has been a major success for the snow and ice control community and appears to be on a growth track to further deployments. FHWA launched efforts to assemble stakeholders in areas outside of winter maintenance to determine what operational requirements needed to be addressed.

On February 27-28, 2007, FHWA held the "Maintenance and Operations Decision Support System (MODSS) Maintenance Beyond Snow and Ice Control Users Workshop" in an effort to gather requirements for operational decision making from state DOT personnel on current practices related to maintenance beyond snow and ice control. Participants from Colorado, Indiana, Minnesota, New Jersey, North Carolina, Texas, Utah and Washington representing DOTs with different climates, terrain, population characteristics, and practices participated. Following the processes used in the initial STWDSR stakeholder meetings, the attendees contributed their ideas to the pool of requirements that will be used to create a Concept of Operations for a decision support system focused on maintenance operations outside of snow and ice control.

On March 1-2, 2007, FHWA held the “Maintenance and Operations Decision Support System (MODSS) Traffic Management User’s Workshop” in an effort to gather requirements on current practices related to traffic management. Participants from Colorado, Illinois, Indiana, Maryland, Minnesota, New Jersey, Texas, and Utah participated. Similar to the MODSS Maintenance Beyond Snow and Ice Control meeting, the attendees contributed their ideas to the pool of requirements that will be used to create a Concept of Operations for a decision support system focused on traffic management operations. Some of the examples for consideration were the requirements for traveler information, incident management, and signal control.

Next steps for FHWA will be to turn these Concepts of Operations into high level requirements, create detailed requirements and finally engineer software as a new module to MODSS. Figure 1 illustrates how various elements are envisioned to interact and expand the functionality of MDSS as it evolves into the MODSS.

Performance and Payback

Performance

Input from field and management personnel obtained from interviews and presentations at the stakeholders meetings is that the overall concept of the MDSS makes good operational sense, gives them a check on their decisions and improves their ability to optimize treatment strategies. Field personnel expressed concern that treatment recommendations tend to slightly under estimate the amount of chemicals needed, so most increase the application amount to insure they have a margin of safety. This is a reasonable approach for users as they become more confident with system capabilities. In response to these field concerns, further research has been conducted and released in NCHRP Report 526, “Snow and Ice Control: Guidelines for Materials and Methods” which deepens the science of anti-icing and expanded and refined the chemical requirements to allow for dilution caused by traffic volume and speed, precipitation type and rate, treatment cycle time and presence or absence of ice/pavement bond, that when included in revised algorithms will likely bring treatment recommendations closer in line with field experience.

In my interviews with Iowa users they doubt that the Iowa DOT gets much of a return on their investment because the recommended treatments are usually consistent with what they would have decided to use without the advice of MDSS. In my opinion this confirms that MDSS is doing an excellent job since each of these supervisors using MDSS are experienced and both they and their operators have completed the AASHTO AI/RWIS computer-based training program so all are sharing a common base of knowledge with MDSS when it comes to decision making.

In situations where the MDSS provided a recommended treatment different than what the supervisor would use, it could be traced back to an inaccurate weather forecast, faulty RWIS data or the users failed to provide feedback to the MDSS that a treatment had been made.

Field users are generally not happy with the speed which their computer operates. This is not a problem within the MDSS, but is a reality that field locations have to deal with. Most of them have the satellite-fed DTN Weather Center in their garage. These units refresh and operate about as fast as a person can point and click which sets the performance expectations high for what they feel MDSS should do.

In my interviews with Minnesota DOT they are working on solutions to correct the slow speed connections and hope to have solutions in place by next winter. They also plan to have 100 snow plow trucks equipped by the 2007-2008 winter with new automatic vehicle location (AVL) with sensing equipment so operations can be reported and fed into the (Pooled Fund) MDSS system in near real time. This should improve the responsiveness of the MDSS.

The improvements that NCAR made to the MDSS made a significant improvement in the road weather forecasts and the resulting treatment recommendations. When Colorado encountered their "Blizzard of 2006" the December 24, 2006 Denver Post reported: "…In northern Colorado, CDOT has used the MDSS system successfully for a year, said Phillip Anderle, a deputy transportation maintenance supervisor. 'The weather forecasting tool has been very, very close to predicting the start and stop times of precipitation,' Anderle said. 'And we're being more efficient, putting out the right product at the right time in the right amounts.' "

On March 14, 2007, the National Transportation Operations Coalition sponsored a Talking Operations Web Conference on Road Weather Management. The webcast with audio and presentation slides are available at http://www.ntoctalks.com/web_casts_archieve.php. Pat Kennedy, City of Denver Public Works, Street Maintenance in his presentation, "Use of MDSS by the City and County of Denver" discussed how they worked with the National Center for Atmospheric Research NCAR and used MDSS in the winter operations and during the blizzard of 2006. He stated "…their forecasts were extremely accurate…". When questioned what "extremely" meant, he said the critical items such as precipitation start times were within an hour…other predictive data like pulse moisture, wind shifts, and holes in the storm…were the items that were helpful in decision making and each were consistently accurate. In his concluding slides he stressed the importance of MDSS in their snow response strategy and the improved level of service to the public. Future applications for severe summer weather would assist them in paving and striping operations and in emergency operations like road closures and localized flooding.

Pay Back

State DOTs reported 200% to 1,300 % return on investment in a National Cooperative Highway Research Program March 2001 report. These benefits included safer travel, increased level of service, cost savings and environmental quality [Reference 7]. The Insurance Company of British Columbia estimated $350,000 to $750,000 in accident savings in one city and an annual province savings of $6 million in windshield damage by using anti-icing snow and ice control [Reference 7]. Both of these studies were completed before MDSS was deployed. The Iowa DOT estimated they had a potential 10 to 15% (about $3.5 million per year) operational savings in their materials and labor costs from MDSS [Reference 8].

To provide 'quantitative' justification for state and local government investments in MDSS, FHWA is conducting Analysis of Maintenance Decision Support System (MDSS) Benefits and Costs with the Maine DOT in their use of MDSS during the winter of 2006-2007. The objectives of the Analysis are to:

- Identify, characterize, and quantify the costs for winter maintenance operations during one winter season to be used as a baseline for comparison. The quantification should include (but not be limited to) the costs for labor, equipment, and materials (e.g., chemicals and fuel).
- Identify, characterize, and estimate the costs of deploying MDSS in state transportation agencies, using Maine as an example.
- Identify, characterize, and estimate the benefits of deploying MDSS in state transportation agencies.
- Calculate a benefit-to-cost ratio for MDSS deployment that can be used as part of the justification for implementing such technologies.

It is anticipated that a portion of the results of this analysis will be available and can be reported at the October 2007 TAC Annual Conference.

Also the Iowa DOT in cooperation with Meridian Environmental Technology is conducting a quality check on their winter road weather forecasts. During the winter of 2006-2007, Meridian, after each winter event, called each member of the Iowa DOT RWIS Committee to discuss the quality of the forecasts that they provided. Concurrently, a member of the Iowa DOT Office of Maintenance is comparing forecasted bridge and roadway temperatures with actual RWIS readings. Also the accuracy of each precipitation forecast is being checked with actual ASOS data and field supervisor's written logs. It is anticipated the quantitative results of this quality check will be available and can be reported at the October 2007 TAC Annual Conference.

Future Directions for MDSS & MODSS

<u>MDSS</u>

- FHWA is continuing to fund some research and improvements for the federal MDSS prototype. Release 5.0 software will be available to any stakeholder during the fall of 2007. NCAR will provide some technical support to answer questions about this new release.
- NCAR will continue to run the federal prototype MDSS for the City and County of Denver
- FHWA will sponsor the 9th stakeholder meeting in the fall of 2007 and pursue sponsoring future stakeholder meetings jointly with AASHTO and/or others
- FHWA and AASHTO will continue to market MDSS
- AASHTO will continue building MDSS into its AI/RWIS computer-based training program
- MDSS will be presented during the National Symposium on Surface Transportation which will be held in Washington, D.C. in June 2007.

<u>MODSS</u>

- FHWA will continue to work with requirements gathered during the MODSS "Maintenance Beyond Snow and Ice Control User's Workshop" and "Traffic Management User's Workshop" by creating a concept of operations, requirements documents and a new module in MODSS.
- AASHTO will participate with FHWA in developing and deploying the MODSS and assist with technology transfer.

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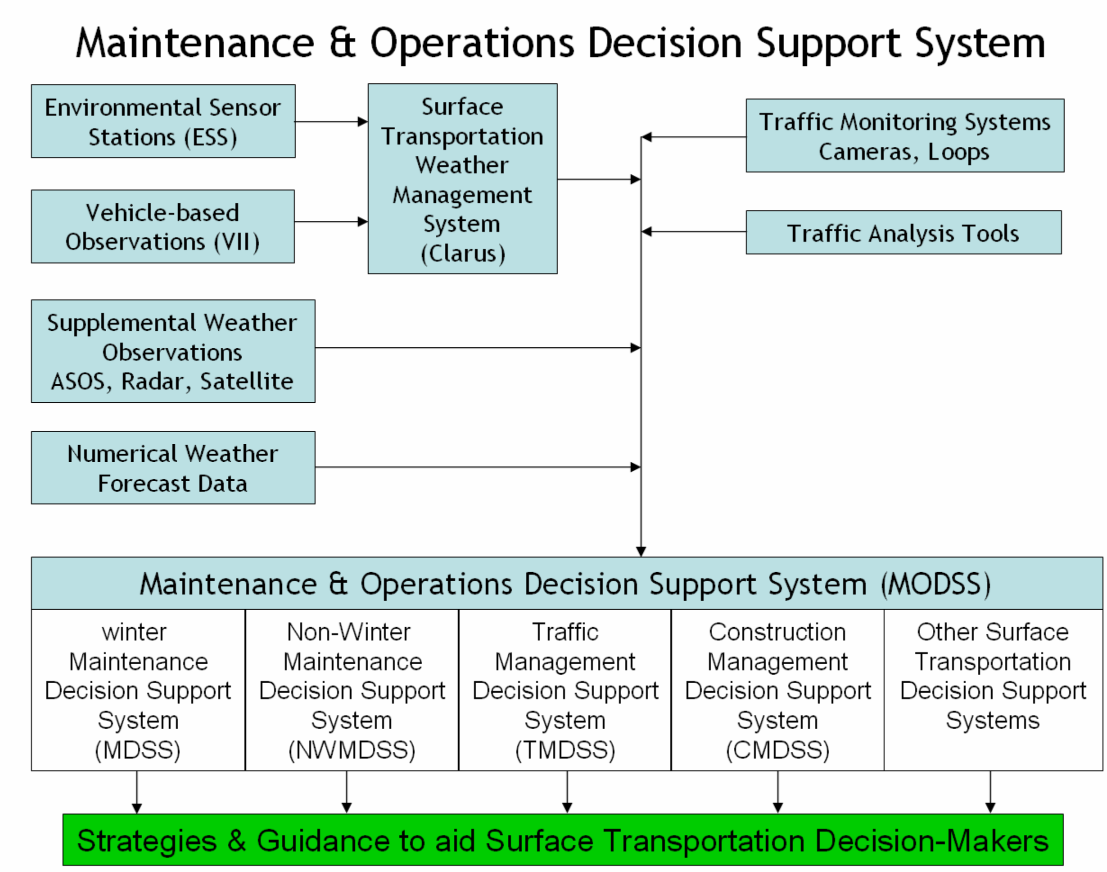
Figure 1


Maintenance & Operations Decision Support System
Environmental Sensor Stations (ESS)
Vehicle-based Observations (VII)
Surface Transportation Weather Management System (Clarus)
Traffic Monitoring Systems Cameras, Loops
Traffic Analysis Tools
Supplemental Weather Observations ASOS, Radar, Satellite
Numerical Weather Forecast Data
Maintenance & Operations Decision Support System (MODSS)
winter Maintenance Decision Support System (MDSS)
Non-Winter Maintenance Decision Support System (NWMDSS)
Traffic Management Decision Support System (TMDSS)
Construction Management Decision Support System (CMDSS)
Other Surface Transportation Decision Support Systems
Strategies & Guidance to aid Surface Transportation Decision-Makers