Surface Transportation Weather Issues for the 21st Century

Leland D. Smithson
American Association of State Highway and Transportation Officials
1801 20th Street, Unit 1817
Ames, IA 50010
ljsmithson@msn.com

ABSTRACT

Transportation agencies in the United States are facing financial and staffing difficulties while the motoring public is asking for improved, year-round mobility and increased safety. At the same time, some agencies are facing extreme environmental problems caused by highway maintenance operations, especially from chemicals used in winter maintenance operations. Since the political outlook for increased taxes to fund highway maintenance is bleak, the only option available for public agencies to solve these problems is to use more efficient and effective methods to accomplish maintenance. Cutting edge improvements for surface transportation weather, now on the threshold of implementation, offer unlimited opportunities for safety, mobility, and operational improvements.

This paper will summarize technological advances and report on the progress in three major areas of surface transportation weather and show how they are anticipated to improve the safety and mobility of the nation’s roadways and the productivity of operating agencies. The following topics will be discussed:

- Improved Road Weather Information Systems (RWIS)
- Aurora Consortium Project 7.9, Temperature Sensor Accuracy
- NCHRP Project 6-15, Testing and Calibration Methods for RWIS Standards
- FHWA and AASHTO SICOP Project, Development of RWIS Environmental Sensor Station Siting Guidelines
- Establishment of a national road weather information observation system
- FHWA Project Clarus—the Nationwide Surface Transportation Weather Observing and Forecasting System
- Recommendations by the National Academy of Sciences in their 2004 report, “Where the Weather Meets the Road: A Research Agenda for Improving Road Weather Services”
- Implementation of a winter maintenance decision support system (MDSS)
- An FHWA MDSS Project that integrates state-of-the-art weather forecasting, data fusion, and optimizing techniques with computerized winter road maintenance rules-of-practice logic. The result is guidance aimed at maintenance managers that provides specific forecast of surface conditions and treatment recommendations customized for individual plow routes.
- Field evaluations showing that MDSS optimizes the use of snow and ice control chemicals and thus reduces their environmental impact and increases their effectiveness.

Key words: decision support—road weather conditions—weather observation
INTRODUCTION

Safe, reliable, all-weather, every-season mobility continues to be the demand of the motoring public. The increasing expectations of the motoring public are a major challenge to transportation agencies, now facing financial and staffing difficulties. Meeting these demands poses unique problems during inclement weather. Rain, fog, snow, and ice significantly affect the safety and capacity of a roadway. However, quality road weather observations and forecasts specific to the roadway environment have the potential to help users, including drivers, maintenance personnel, fleet dispatchers, enforcement officers, traffic managers, and emergency personnel, make better decisions, thus increasing travel efficiency and safety during adverse weather conditions. Cutting edge improvements for surface transportation weather, now on the threshold of implementation, integrated with enhanced decision making techniques, offer unlimited opportunities for safety, mobility, and operational improvements.

SURFACE TRANSPORTATION WEATHER OBSERVATIONS

Surface weather is different from upper atmospheric weather because of ground interaction. This results in the information provided by a traditional forecast often being inadequate for effective surface transportation-related decision making. The reason is air, humidity, precipitation, pavement orientation, surface and subsurface temperatures, and traffic all come together at the pavement surface to create an environment that can be much different than that occurring a few feet above the ground. The foundational investigative work for road surface weather took place in 1988 in the Strategic Highway Research Program (SHRP) and was published in 1993 (Boselly et al. 1993). The road weather information systems (RWIS) were installed generally using manufacturer’s recommendations and local maintenance supervisor knowledge. Often these RWIS sites were installed in problem areas (high-accident, coldest spots, frost-prone areas, etc.) and did not represent regional road weather conditions. Little was known about testing and calibration of these systems or the accuracy of the sensors.

Figure 1 shows a typical RWIS environmental sensor station (ESS). RWIS consists of the hardware, software, and communications interfaces necessary to collect and transfer road weather observations from the roadway to a display device at a user’s location. While the original purpose of RWIS was to address winter weather conditions, applications have been developed to detect and monitor a variety of road weather conditions impacting road operations and maintenance, thus providing opportunities to serve a wider array of users.

![Improved road weather information systems (RWIS)](image)
RWIS Siting Guidelines

The Federal Highway Administration (FHWA), recognizing the need for a national uniform identification of RWIS, published “Road Weather Information System Environmental Sensor Station Siting Guidelines” in April 2005 to provide guidance for siting an RWIS ESS and its associated environmental and pavement sensors (FHWA 2005). The guidelines provide siting criteria that satisfy as many road weather monitoring, detection, and prediction requirements as possible.

Most state DOTs do not have a detailed inventory of their RWIS ESS system, so a national uniform inventory will need to be undertaken. The FHWA guidelines provide the desired elements of this inventory and emphasize the importance of documenting each site’s metadata. Metadata are defined as data about data. Metadata should consist of information about the site location; elevation; topography; soil; surrounding vegetation; relationship to the roadway surface; exposure of the site to wind, sun, moisture sources, and artificial temperature; accuracy of sensors; measurement range of sensors; sampling time and intervals; and an indicator of the quality of the exposure of the sensors. (Note that these indicators have not yet been developed). Once a national inventory is completed, the RWIS ESS data will be useable by the wider transportation and meteorological communities.

RWIS Temperature Sensor Accuracy

The Aurora Program, a consortium of agencies focused on collaborative research, evaluation, and deployment of advanced technologies for detailed road weather monitoring and forecasting, recognizing the need for accurate sensor data, completed a study entitled “Pavement Temperature Sensor Accuracy.” The project determined the accuracy and variation in readings of various pavement temperature sensors, both in-pavement and mobile, by first developing a method to determine true pavement temperature for comparison purposes by the following processes:

- Compared sensor readings in a controlled laboratory environment
- Compared sensor readings in an operational environment
- Compared sensor readings under various temperature and weather conditions
- Compared the effects of commonly used road deicing and anti-icing chemicals on sensor readings
- Compared the effects of traffic on sensor readings

Summary results show that overall the temperature sensors reported surface temperatures within 0.8° C of the actual pavement surface temperature. Also, the application of sodium chloride to the sensors had an insignificant impact on sensor temperature performance. Solar impact was difficult to reproduce in the laboratory environment, so it was listed as suggested research into the effects of radiational cooling and solar heating for a better understanding of RWIS sensors. The final report outlining how well various sensors worked and their conditions is posted on the Aurora website at http://www.aurora-program.org.

Testing and Calibration Methods for RWIS

The National Cooperative Highway Research Program (NCHRP), recognizing that most agencies either rely on vendor-developed testing and calibration methods or simply accept sensor data without verification or regular and timely calibration, is developing guidance for the practical testing of RWIS ESS to ensure that sensors are providing an accurate representation of actual site conditions. A contract was awarded in June 2003 to develop concise guidelines of best practices for RWIS ESS testing and calibration methods in field deployments. The final report, complete with guidelines that can be distributed as a stand-alone document for use by RWIS end-user organizations, will be available in the fall of 2005.
ESTABLISHMENT OF A NATIONAL ROAD WEATHER INFORMATION OBSERVATION SYSTEM

National Research Agenda for Improving Road Weather Services

In the past few years, weather-related transportation issues have become a priority for the national research agenda. The FHWA funded the Board on Atmospheric Sciences and Climate (BASC) of the National Research Council to examine the research that needs to be done and the technology transfer that should be accomplished to improve the production and delivery of weather and road weather (road weather is the micro-climate at the road’s surface) information for the nation’s roadways. The results of that study were published in an April 2004 report entitled Where the Weather Meets the Road: A Research Agenda for Improving Road Weather Services (NRC 2004). The report concluded that forecasting and handling road weather is a highly interdisciplinary problem, spanning micrometeorology, numerical weather prediction, vehicle technology, meteorological and pavement instrumentation, roadway construction and maintenance, human factors, and technology transfer. The report is available at the National Academies website: http://www7.nationalacademies.org/basc/publications.html.

At about the same time in 2003, the American Meteorological Society (AMS) decided to hold a forum to address various issues connected with the effective use of road weather information. The AMS Atmospheric Policy Program organized a “Weather and Highways Forum” and invited nearly 100 public and private transportation managers and users, representatives of weather information providers, academia, and policy makers knowledgeable about the nation’s highway system, to participate in a two-day forum in Washington, DC. More information is available at the AMS website at http://www.ametsoc.org/atmospolicy/2003transportationforum.html.

Both the BASC report and the AMS policy forum put forth a suite of research activities and other efforts to foster the implementation of an improved road weather program. The AMS “Weather and Highways” report (AMS 2004) sets forth a concise six-point program as follows:

1. Congress should authorize and provide long-term funding for the appropriate federal agencies to develop a national road weather research, development, and applications program to improve the application of weather information for highway safety and operations.
2. The federal and state departments of transportation should closely coordinate with public, private, and academic sector road weather stakeholders to improve the safety and efficiency of the nation’s highway system during adverse weather.
3. The US DOT/FHWA and the National Oceanic and Atmospheric Administration (NOAA), working with state DOTs, should establish a national road weather and road condition data collection, processing, and dissemination infrastructure to improve the safety and efficiency of the roadway system.
4. NOAA/NWS, commercial weather providers, and weather information users should work cooperatively to improve the observation system, develop and improve forecasts, and enhance the delivery of information and services on road weather.
5. Federal and state DOTs should train the road management community to integrate weather into the decision process more effectively. In addition, the atmospheric science community, particularly academia, should develop course curricula focusing on road weather science and engineering.
6. The US DOT/FHWA should provide incentives for vehicle manufacturers and highway engineers to raise public and private sector demand for in-vehicle road weather information.
Establishment of a National Road Weather Observation System

Following recommendations 3 and 4 listed above in the BASC report and the AMS policy forum, FHWA developed a project called the Clarus Initiative, which establishes a vision for leveraging local and regional road and rail weather observations to serve a greater community and enhance 21st century transportation operations. This vision will be accomplished through the design, demonstration, and deployment of a national surface transportation weather data collection and management system that complements the existing National Weather Observation System with RWIS ESS and other surface observations. Surface transportation-based weather observations integrated with the existing National Weather Observation System data will provide broader support for surface transportation-specific models to predict impacts on surface transportation operations, safety, and mobility.

At the writing of this paper, the Clarus Initiative was finishing writing the Concept of Operations, which provides a high-level definition of how the system will work. A great deal of time has been spent on establishing and understanding of the needs of various stakeholders and how the Clarus System can be structured to meet user requirements. Functional scenarios are being developed for the many market segments that will be served by the system. Stakeholders and the consultant are involved in preparing a narrative text with an illustrated Use-Case Diagram and a Sequence Diagram addressing the typical concepts anticipated to exist in the application of Clarus System data.


IMPLEMENTATION OF A WINTER MAINTENANCE DECISION SUPPORT SYSTEM

Background

In 2000, the Office of Federal Coordinator for Meteorology and the FHWA Road Weather Management Program, in an effort to capture surface transportation weather requirements and unmet user need, cosponsored symposiums on weather information for surface transportation. The author of this paper participated in those symposiums. The symposiums brought together users and providers in an effort to capture surface transportation weather requirements and identify unmet user needs. An unmistakable message emerged that users were not satisfied with the current surface transportation weather capabilities and that much more could be done to address their needs. Although weather forecasts were plentiful and a few private service providers issued road-specific forecasts, there was a lack of linkage between the information available and the decisions being made by winter maintenance managers. Thus, the FHWA Road Weather Management Program decided to address some of the unmet weather needs by launching the Maintenance Decision Support System (MDSS) project.

During the past four years, MDSS has evolved into a functional prototype system. A prototype MDSS was deployed at several maintenance garages in central Iowa in winter 2002–2003. During the winter of 2003–2004 a second, more comprehensive field demonstration was conducted. As one would expect, the performance of the prototype MDSS was much improved during the second winter of use, but still not sufficiently mature to convince the private sector that the system was ready to market or convince the public sector to require MDSS as part of their forecasting specifications. A third field demonstration was held in Iowa during the winter of 2004–2005 and a first demonstration was held in the more difficult terrain and climate of Colorado.
Project Resources and Organization

The MDSS research project is funded and administered by the FHWA Road Weather Management Program. The project builds upon the work accomplished in the SHRP and the Test and Evaluation Project TE-28 that FHWA, the American Association of State Highway and Transportation Officials (AASHTO), and the Transportation Research Board (TRB) completed in the mid-1990s. A consortium of five national laboratories in coordination with state DOTs, academia, and the private sector have been participating in the development and field evaluations of the project. These laboratories include the following:

- Cold Regions Research and Engineering Laboratory (CRREL)
- National Center for Atmospheric Research (NCAR)
- Massachusetts Institute of Technology/Lincoln Laboratory (MIT/LL)
- NOAA Forecast Systems Laboratory (FSL)
- NOAA National Severe Storms Laboratory (NSSL)

Both CRREL and MIT/LL had participated in the SHRP and TE-28 projects, so they brought some familiarity and background to the project. CRREL brought experience in creating models for predicting road surface temperature while MIT/LL concentrated on translating the road maintenance rules of practice into computer algorithms. FSL provided high resolution weather models while NSSL contributed algorithms for determining precipitation type in weather models. NCAR was the lead laboratory providing the core data processing capability, the graphical user display, and the engineering to integrate all the parts into a working MDSS prototype.

Project Overview

The MDSS project integrates surface weather forecasting, data fusion, and optimization techniques with the computerized anti-icing techniques of the TE-28 project rules-of-practice logic. The result is a specific forecast of surface conditions and treatment recommendations customized for individual highway sections.

The MDSS project goals include the following:

- Show state DOTs that new technologies can be integrated to provide maintenance managers decision making support in improving safety and mobility on roadways while making more efficient use of chemicals, equipment, and staff.
- Convince private sector surface weather providers that there is a market for these new technologies.

FHWA-defined success for this MDSS project would be reached when private sector companies integrated MDSS components into their product lines and state DOTs were writing MDSS requirements into their purchase specifications.

Field Evaluations

Six state DOTs competed to win the opportunity to evaluate the prototype MDSS. Factors used in selecting the winning candidate were the availability of high-speed communications and computers at the maintenance garages, progressive winter maintenance programs, and a willingness of the DOT personnel to participate in training and field verification activities. The Iowa DOT met those criteria and did not have complex terrain.
The first demonstration period began February 3, 2003 and concluded April 7, 2003. A total of 15 plow routes in 3 maintenance garages around Des Moines and Ames, Iowa were selected. During that time, five light snow events (three inches or less accumulation), three heavy snow events (more than three inches), and one mixed rain/snow/ice event occurred. The demonstration was a success because the prototype was deployed and utilized and the following list of lessons learned was compiled:

- The prototype was unable to capture light precipitation events, which caught crews off guard.
- The rules-of-practice module needed additional development to handle a wider variety of weather and road condition scenarios and treatment responses.
- The availability and quality of observed real-time precipitation rate and accumulation data were very poor for snow and ice.
- The prototypes needed algorithms in the road condition treatment model (RCTM) to account for the impact of vehicle speed and volume on chemicals and the complex problem of blowing and drifting snow on the roadway.

A second demonstration was held in central Iowa from December 29, 2003 to March 24, 2004. Although the MDSS graphical user interface (GUI) was highly rated by the Iowa DOT for its ease of use and logical layout, further enhancements were made for the second demonstration. These enhancements included adding digital values to state and route view graphics, a real-time display of RWIS data, a historical window to review guidance from previous forecast cycles, and an event summary of weather and road variables for each forecast period and for each plow route. The GUI is illustrated on the MDSS web site http://www.rap.ucar.edu/projects/rdwx_mdss.

The RCTM and rules-of-practice module were significantly enhanced to recognize the overall storm situation, handle changing weather situations, and provide a blowing snow alert. Other enhancements included modifying the road temperature model to accept actual road temperature and subsurface temperatures as input, rather than relying on model-derived values.

The road weather forecast system (RWFS) was configured to utilize and integrate ten different forecast modules, and probabilistic forecast information was added. Since winter maintenance supervisors are in the business of risk management, the probabilistic prediction products is helpful. Results were that the forecasts had significantly better skill in the first six hours because of their forward error correcting capability, but still had poor-quality precipitation measurements. Also, the ability of models to predict insolation varied greatly between models, particularly in partly cloudy conditions. Since insolation measurements are critical for road temperature prediction, it was recommended that insolation measurements be added to surface observing stations and be provided in real time to weather service providers. Further enhancements to the prototype are explained in Mahoney et al. (2005).

The third year of demonstration, for the winter of 2004–2005, was held in both Iowa and Colorado. The Iowa implementation went well, since most of the problems had been worked out in the previous two years. Several of the recommended treatments were utilized without modifications and proved to be optimal solutions. Others needed only minor tuning. Any that were in serious error were so because of errors in the forecasts.

The demonstration in Colorado had difficulties. The major effort for MDSS was concentrated on the 470 toll road. As in previous demonstrations, the RWFS was configured to utilize and integrate ten different forecast modules. Unfortunately in the complex terrain, there were large spreads between the models, and it was difficult to tune a best model. Work is needed to provide a better coupling between the land surface models to the atmospheric models.
Detailed reports on the third-year demonstration will be developed during the summer of 2005. Results may be available for reporting at the 2005 Mid-Continent Transportation Research Symposium.

**Estimating MDSS Success**

As stated earlier, success as defined by the FHWA will be reached when private sector companies integrate MDSS components into their product lines and state DOTs purchase these new services. Guidance to state DOTs in preparing and evaluating specifications for weather forecasting services that include capabilities similar to those found in the FHWA prototype MDSS can be found in NCAR (2004). This guidance includes the following:

- Candidate functional requirements for MDSS products and services
- Information that DOT personnel can use to evaluate prospective DMSS service
- Questions that could be asked when interviewing prospective vendors

Requests for proposals for weather forecasting services are currently being developed by the Iowa DOT for a summer 2005 letting. MDSS guidance is currently listed in the Mandatory Requirements section. MDSS capability requirements are divided into three-year steps to allow time for the development of the system over the three-year contract period.

The Iowa DOT presented its success with evaluating and implementing MDSS during the past three winters at the 2005 Midwest Snow and Ice Workshop, held in Kansas City, Kansas, on April 19 and 20, 2005. Eleven Midwestern states attended this workshop. All eleven states expressed interest in learning more about MDSS and how it could be evaluated in their states. The MDSS presentation is scheduled for September 8, 2005 at the 10th Eastern Winter Road Maintenance Symposium and Equipment Expo being held in Hartford, Connecticut. The opinion of the author is that some of these Midwestern states and other states beyond the Midwest will soon follow the Iowa DOT’s lead in implementing MDSS and eventually requiring MDSS guidance in their future weather forecasting services.

**CONCLUSION**

The first part of this paper addressed identifying and correcting the inadequacies of the current RWIS ESS sites and sensing equipment and the efforts to establish a national road weather observation system. The referenced studies by the FHWA, Aurora, and NCHRP will improve the sensor quality and representative characteristics of each site. The Clarus Initiative will provide quality assurance of the data stream. The Clarus System operational attributes call for continuous quality control of data with feedback to state DOTs and other users.

The reminder of this paper addressed the MDSS project with its integrated state-of-the-art weather forecasting and data fusion and treatment optimization techniques. Field evaluations show MDSS will provide maintenance managers with a specific forecast of road surface conditions and optimized treatment recommendations customized for each plow route, thus maximizing the efficiency and effectiveness of snow and ice control operations.

Stakeholders in these projects have expressed their confidence that quality data, transferred in one common protocol with full metadata, as envisioned in the Clarus Initiative, will result in more effective and proactive operational decision making and better performance of meteorological support services. Quality data provided to travelers will build their confidence and help them develop and promote a proactive approach in their decision making process.
Although much as been accomplished in developing “Surface Transportation Weather for the 21st Century”, considerable research, evaluation and testing remains to be done. A common vision and belief that prevails at every stakeholder meeting is that these unlimited opportunities for safety, mobility, and operational improvements are achievable.
REFERENCES


