

A POLICY FORUM: WEATHER AND HIGHWAYS

developed by the

**ATMOSPHERIC POLICY PROGRAM
AMERICAN METEOROLOGICAL SOCIETY**

in coordination with the

Federal Highway Administration (FHWA)

with additional support from the

National Science Foundation (NSF)

Study Series Underwriters



Raytheon

Panel 1

**Present And Near-Term Potential In Applying
Weather Information To Improve The Highway
System**

POSITION PAPERS

Present and near-term potential in providing weather information to improve the highway system

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1. What improvements are needed on the observational, technological, and modeling capabilities to significantly increase the nation's safety on the highway system during adverse weather?

Summary Response:

a) Precipitation Prediction: Without a doubt, an improvement in the prediction of precipitation is the most important item. Improvements in the timing of precipitation events (start and stop times), precipitation rates (including liquid equivalent for snow) and precipitation type are required. Improved precipitation prediction would benefit winter maintenance operations as more informed decisions could be made on the timing, location and effectiveness of anti- and deicing treatments. Winter road maintenance decisions are generally based on having answers to the following questions specific to each maintenance route:

- When will the event start and stop?
- How is the road temperature changing?
- Will the roads be wet when they freeze?
- What type of precipitation will fall?
- How much precipitation will fall
- At what rate will precipitation fall?
- When will the anti-icing and/or deicing chemicals fail due to dilution?

Incident management with respect to flood control could be more effective and traffic management decisions could be more effective if decision makers had better knowledge of the regions where precipitation (rain, snow and ice) was going to occur. Incident management involves preparing for and responding to crashes or incidents that impact the normal flow of traffic. Many factors contribute to incidents including excessive speeds, tailgating, work zones, curiosity slowdowns, and sun glare. Weather, particularly rain, snow, ice and low visibility, has a significant impact on the incident rate. Individual incidents and their impact on traffic flow could be reduced if the travelers and incident responders knew where the precipitation was going to occur in advance. For example, if personnel at the traffic management center knew there was a high correlation between wet roads and incidents in a particular location, they could position police and tow vehicles appropriately to respond just before the precipitation occurs.

b) Winter Precipitation Measurements: The transition from manual to automated weather observations has been posed some problems. A large problem with the manual observations is the accuracy and internal consistency of some measurements. Of particular importance to surface transportation is an accurate measurement of precipitation type and rate. The transition from rain to snow often results in ASOS reports of "unknown" precipitation and there are frequent snowstorm events where zero liquid equivalent precipitation is reported for the entire event. In general, there is a significant underreporting of winter precipitation types by automated systems. Because the precipitation type and rate impact the road temperature and treatment requirements, an accurate measurement of

precipitation is required. Light precipitation amounts (~0.1mm/hr) are particularly important. This impacts tactical decision-making and negatively impacts weather prediction systems that statistically calibrate themselves using observations. Better winter precipitation measurements and real time reporting will benefit all users of precipitation data and will also provide a more accurate verification dataset for research activities and climate datasets. Attention must be given to improving key surface transportation weather observations.

- c) Sharing Weather Observations: State DOTs and numerous other agencies and organizations deploy and measure surface weather observations. Although the accuracy of these data are sometimes unknown, they are quite useful to numerous economic sectors (e.g., agriculture, railroads, highway departments, energy, construction, etc.). These data should be shared openly with all stakeholders. Some issues remain open including determining the appropriate lead agency to ingest, quality control and disseminate the data. The Meteorological Assimilation Data Ingest System (MADIS) program at NOAA/Forecast Systems Laboratory (FSL) provides a good template for this within NOAA. Metadata is also an important element of these data and more attention should be given to ensure that metadata are appropriately categorized and recorded. Given the economic benefits of these data sets, it seems appropriate that NOAA/NWS champion the data sharing effort.
- d) Radar Data Quality: The role of radar data in the decision process will increase dramatically as traffic and incident management, maintenance decision support systems, and in-vehicle information systems and communication networks are developed and implemented across the surface transportation infrastructure. Precipitation data will play a key role in these tactical decision support systems. Current and planned radar data upgrades such as the availability of Level-II data, improved anomalous propagation (AP) suppression, dual polarization, and techniques that dynamically calibrate precipitation rates using gauge data, will go a long way to improve the timeliness and accuracy of these datasets.
- e) Water Vapor & Visibility: Fog and other visibility reducing phenomena have a major impact on safety and capacity of the roadways. Multi-vehicle crashes occur every year due to fog. New and better observations of clouds and fog are required as well as new data fusion technologies to better diagnose the occurrence of fog and low visibility regions.
- f) Insolation Measurements: Knowledge of road temperature is critical for anti- and deicing operations. Heat balance models are used to predict the road surface temperature and one of their key inputs is short and long wave radiation. Road temperature prediction models rely on weather model output of cloud height, density, and, where explicitly available, insolation. There are few direct observations of the actual insolation. If insolation data were routinely available along roads (co-located with road weather measurement systems), they could be used to initialize road heat balance models and for verification and tuning of the models.

2. How is weather information communicated to the highway system decision makers and what improvements should be made?

Summary Response:

- a) Paradigm Change: Across the country, the information revolution has made it much easier to move data to decision makers. Coded textual data streams are being replaced with graphics and interactive processing systems reducing the need to translate or geo- reference weather

information. Inexpensive computers, personal digital assistants, the Internet, cell phones and short range digital radio are all coming together in the transportation community, much like everywhere else with a great deal of potential. The Intelligent Transportation System (ITS) community sometimes refers to the combination of information technologies as the *Transportation Infostructure*. The technology revolution has only just begun with respect to the surface transportation industry and traveling public. This transition has occurred more slowly, and in some cases much more slowly, in this community. There are still a large number of highway supervisors and operators and commercial fleet operators that make critical decisions based on low-resolution weather information gathered from multiple sources including national and local newspapers, national and local television, and cable programs. This swivel chair integration requires the end user to interpret the information, form an opinion on its accuracy and then make a risk based decision. The “information revolution” provides an opportunity to improve the manner in which weather information is provided to the decision maker.

- b) Weather Content and Consistency: Weather information must become more accurate and be tailored to support the specific decisions of the decision maker. The decision maker is not necessarily just the traffic manager or maintenance manager. He or she is more likely to be the person driving the vehicle. An effort should be made to begin thinking of ways to get the weather information, particularly hazardous weather information, in front of all the stakeholders in formats that can be easily interpreted by non-meteorologists and in a common format so there is no user confusion as they travel through different jurisdictions or get information from different providers.
- c) Weather Information Delivery: In order to improve roadway efficiency, capacity and safety, new information technologies are being developed that will allow real time updates of weather, traffic, work zones and accidents within the vehicle. Dynamic data will be sent to vehicles via telematic systems where the data will be coupled to navigation software. For example, if you are in your car and a hail storm is ahead, the information on the storm will be geo-referenced with the GPS position of the car and a voice alert will inform you that the event is ahead. An alternate route may be suggested if you have configured your on-board system to provide this type of guidance. This type of technology is coming and the weather community needs to be ready to deliver uniform and consistent content.

A new telephone capability is spreading across the country. National 511 is a program that provides real time weather, road condition, traffic and incident information via the telephone or cell phone by dialing 511. Several states have this technology now and several more are in the process of obtaining it. How well is the weather community supporting this effort? It is clear from user needs assessments that more specific weather information is required by most user categories. Research will be needed to improve the accuracy and specificity of the information provided. National standards should also be developed to ensure information consistency between states.

- d) Probabilistic Weather Products: Transportation decision makers, like most decision makers, are generally in the risk management business. Decisions are made to reduce costs, increase safety, and improve efficiency. In the transportation sector, weather plays a critical role in this decision process. One of the reasons the decision makers seek multiple sources for weather information is to get an indication of confidence in the forecast. If all the sources agree, there is a perception that the event will play out about as predicted. Because weather will never be predicted perfectly at road scales, probabilistic products should be developed, implemented, and promoted. The weather community needs to do a better job conveying certainty or the lack thereof. This requires

atmospheric, statistical, and human factors research to ensure the end user is getting consistent information and understands its content.

3. What are the opportunities for and barriers to effective application of weather information to highway safety and operations?

Summary response:

- a) End User Training: The surface transportation user community is not well versed on weather technologies and the potential benefit of proactively integrating weather in their decision process. In the road operations and maintenance arena, experience is critical. Unless the decision makers are comfortable with the information or technologies they are using, they will tend to shy away from them. The lack of comfort or experience with new technologies may be exacerbated by the high staff turnover rate at the State DOTs, which is expected to worsen as the baby boomers retire. It is critical that weather education and training programs for transportation professionals be focused on how weather information can be used to optimize operations. The American Association of State Highway and Transportation Officials' (AASHTO) computer based learning program for effective snow and ice control is an excellent example of a training program focused on helping the decision maker make better use of weather information in their decision process. Both onsite and remote training programs (first time and recurrent) should be established for a broad range of road weather topics. The lack of resident weather expertise in most DOTs begs the question as to whether DOTs should employ a full time road weather meteorologist as a resource that can provide weather support across the organization.
- b) User Benefits: The impact and economic benefits of improved highway weather information need to be gathered for several decision categories (e.g., incident management, traffic management, winter maintenance, evacuation, etc.) in order to highlight the potential benefits of improved weather information. The current lack of benefit information may be a barrier as the payoff for utilizing weather information is not always clear.
- c) Education Programs: The U.S. is decades behind Europe and Japan when it comes to road weather research and applications development. Until recently, there were no university programs in the U.S. that had road weather in their curriculum. Should the academic community be encouraged to develop curriculum focused on surface transportation? Programs need to be interdisciplinary (physics, atmospheric science, computer science, civil engineering, etc.) and focused on the practical application of weather information.
- d) The Public-Private Partnership: The FHWA does not own or operate any highways so weather information technologies will only be adopted when road operating agencies are ready to do so. Operational weather technologies developed for highway use must be transferred to organizations that can provide that service. The path to operations can be complicated and could act as a barrier to implementation. Because of the fundamental way highways are operated, weather research, development, and implementation programs must recognize that the private sector and road agencies must be involved in the development cycle. A public-private partnership paradigm should be used and the resulting technologies made available to the community on a nonexclusive basis.

- e) Coordination at the National Level: In order to successfully meet the needs of the surface transportation community (Ref. OFCM Weather Information for Surface Transportation – A National User Needs Assessment), a coordinated weather program needs to be established at the national level. The program must be adequately funded and include research, development, implementation, verification, training, outreach, and education. It must cut across multiple transportation operations categories and involve the stakeholders.

An example of a successful weather program within the DOT is the FAA's Aviation Weather Research Program (AWRP). The AWRP has existed for 10 years and has significantly improved aviation weather detection and prediction and product delivery to end-users. Research and development topics cover windshear, in-flight icing, deicing, turbulence, convection, ceiling and visibility and ocean weather hazards. End users have been involved from the beginning, it has saved lives and it has FAA and airline industry support. However, significantly more deaths, incidents and capacity problems exist on the highways. It seems prudent to advocate for a broad based surface transportation weather research and development program designed to improve roadway safety and capacity.

Weather Information for Surface Transportation

Greg Mandt
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We cannot control the weather or its effects on our transportation systems. We can, through quality observations, provide critical information necessary to mitigate or avoid the negative impacts of adverse weather. The Weather Information for Surface Transportation (WIST) provided customer insight into what the National Weather Service (NWS) needs to do to provide better weather information to each of the transportation sectors. Samuel Williamson, Federal Coordinator for Meteorological Services and Supporting Research stated it best, “We must re-invigorate existing support capabilities, initiate creative new solutions, and exercise judicious use of assets to maximize the cooperative interests of government and private sector participants for the benefit of the surface transportation public we serve.”

The WIST document provides the framework and guiding principles for meeting the diverse needs of each transportation sector and other partners in the public and private sectors. The program has six strategic thrust areas:

- ✓ *The Identification of Gaps in Coverage of WIST Needs.* This requires the identification and validation of user needs that cannot be met with existing information resources. This will require NWS support in the conducting of a gap analysis, assisting in the establishment of siting and performance standards for current and future observation and monitoring platforms.
- ✓ *Expanding Coordination Among WIST R&D Programs and WIST Providers.* The NOAA must operate a robust R&D program to ensure continued product and service improvement. Only through partnering with other agencies will we be able to address critical service and research issues. A team approach is also vital to achieving efficiencies in forecasting high-impact weather events.
- ✓ *Clarifying and Defining Provider Roles and Responsibilities.* The primary roles for providing weather information for surface transportation is shared among the public and private sectors. Partnerships are critical and alliances are critical to ensuring that the needs of the surface transportation sectors are met. NOAA will work with its public and private sector partners to ensure success.
- ✓ *Translating Research Results and New Technologies into WIST.* NOAA through groups such as the U.S. Weather Research Program must focus on taking research to operations as quickly as possible. Technology infusion is critical to filling gaps in data monitoring and decision-making tools.
- ✓ *Providing the Fundamental Knowledge to Support Future Technology Development and Application.* The Office of Science & Technology and NOAA’s research arm Oceanic and Atmospheric Research lead NOAA’s efforts as the visionaries who look at current systems with an eye toward future improvements in our ability to reduce economic losses through better spatial and temporal resolution in both observations and forecasts resulting in better forecast accuracy.

- ✓ *Expanding Outreach and Education.* The NWS has embarked on a customer service campaign. Through greater customer interaction the NWS will develop a better understanding of its users needs and expectations. As new technologies and procedures are fielded the NWS will offer its customers outreach and training education.

The uses of road weather information are evolving rapidly. Our ability to monitor and predict the weather has increased substantially. Growing knowledge of the causes and characteristics of the atmosphere is being translated into useful longer lead-time forecasts and greater capability to project future weather impacts. Such improvements has enabled a broader set of applications, serving to enhance the economy, manage risk, and protect life and property. The array of applications and the potential for new applications are enormous.

Surface transportation weather is an increasingly important element of public and private decision making in field as varied as emergency management planning for hurricane landfall evacuations and distribution of energy resources. Increasingly model projections are also being used by decision makers in assess changing issues of importance. NOAA must focus on very different activities in order to address all major categories of atmospheric variability and change. Weather services and products include observations, forecasts, and projections and their uncertainties. Each is associated with different types of users or decision makers and with different needs and products, as is evident with current NWS products and services.

The value of meteorological information depends on many factors, including the strength and nature of linkages between weather and surface transportation activities; the nature of the uncertainties associated with weather forecasts; the accessibility of credible and useful weather information to decision makers; the ability of users and providers identify each other's needs and limitations; and the ability of users to respond to useful information. The increasing realization of the importance of weather information, as describe in the WIST report, is stimulating user demand for improved information which is in turn broadening the scope of weather services.

To be successful in this endeavor, WIST partners must:

- ✓ Define weather services needs.
- ✓ Define potential audiences and providers of weather services.
- ✓ Describe the types of products that should be provided through weather services providers.
- ✓ Outline the roles of public, private, and academic sectors in weather services.
- ✓ Define the fundamental principles that should be followed in the provision of weather services.

The guiding principles for any service include:

- ✓ Activities and elements of service should be user-centric.
- ✓ If a service function is to improve and succeed, it should be supported by active research.
- ✓ Advanced information on a variety of space and time scales is required to serve national needs.
- ✓ Services require active and well-defined participation by government, business, and academe.

WIST must promote more effective use of the nation's weather observation systems through the following:

- ✓ Inventory of existing observing systems and data holdings.
- ✓ Promote efficiency by seeking out opportunities to combine efforts of existing observation networks to serve multiple purposes in a more cost-efficient manner.
- ✓ Create user-centric functions within agencies.
- ✓ Perform user-oriented research.
- ✓ Create incentives to develop and promote observation systems that serve the nation.

WIST must improve the capability to serve the surface weather information needs of the nation through the following:

- ✓ Focus research activities on operational needs.
- ✓ Improve the quality of weather products through technology infusion.
- ✓ Address long-term needs derived from long-term projections through continuous analysis and modeling efforts.
- ✓ Develop better weather products based on ensemble weather simulations.

WIST must address societal needs through the following:

- ✓ Increase support for interdisciplinary studies, applications, and education.
- ✓ Enhance the understanding of weather through public education

The existing network of national agencies, and private sector organizations has provided services in the past and provides increasingly competent services today. NOAA believes that the best practices of the various activities; if applied across all levels of services, local, state, regional and national, would improve the overall weather services to the nation's surface transportation sectors.

Present and Near-Term Potential in Providing Weather Information to Improve the Highway System

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Introduction

Although the development of a national highway system began over one century ago, the support of this system has been focused predominately on construction, renovation and maintenance of this 160,000-mile system. Only since the early 1970's has attention been placed upon the use of existing and future weather conditions to plan for roadway maintenance. Efforts to develop a systemic use of roadway weather information have expanded dramatically in the past decade. These efforts are leading to a concerted effort within the federal, state, academic and private sectors to bring improved weather information to maintenance decision makers and the traveling public. While the federal and academic efforts, albeit limited, have been channeled towards improving surface transportation weather research, the state and private sector efforts have been directed towards improving the operational applications of weather information on highway maintenance and travel information. Although the growth in interest and effort has been dramatic in the past decade, the efforts are still small and fragmented as compared to other research and operations programs such as found within the aviation community.

Observational, Technological, and Modeling Capabilities and Improvements

The capacity within federal laboratories and universities to address basic atmospheric sciences issues leading to development of new technology has been demonstrated many times during the past half-century. No better has this been exemplified in the transportation world than with the advanced aviation weather system that has come to pass since the 1970's. These advancements have been made possible through improved observational capabilities including the development and use of Doppler weather radar, automated surface observation systems, and the conversion of these observations into operational systems providing controllers and pilots the detail of information necessary to promote greater efficiency and safety along the airways.

Although not as dramatic, advancements have also been made within the highway system in the use of road weather information systems (RWIS) through the deployment of environmental sensor stations along a number of the nation's highways. However, a robust deployment of RWIS has been limited by their cost and the strong competition for limited funds within state departments of transportation (DOTs). Further, while the present environmental sensor system technology in use today is more sophisticated than it was just a decade ago, it follows a traditional paradigm of general weather data collection at widely spaced intervals and lacks the representative roadway coverage necessary for use in aggressive site-specific roadway weather forecasting. Present analyses of these data often results in inappropriate spatial smoothing of the information as the point source observations do not represent continuous conditions and the spatial variability can be dramatic over very short distances. In addition, the lack of standards for field calibration, quality control, and siting often hinder the use of the sensor data in the preparation of roadway weather analyses and forecasts. Only in limited situations are statewide RWIS networks designed for joint purposes of supporting specific maintenance challenges and broader meteorological applications. Early RWIS was designed to support maintenance requirements, not to supplement meteorological needs. There was a distinct philosophical momentum in place to only support maintenance needs before the meteorological

community became involved in the potential use of the RWIS data. Further, siting requirements in DOT right-of-way often precludes siting RWIS instrumentation to meet WMO standards. In addition the economics associated with locating RWIS equipment to collect pavement and weather conditions often tilt the decision towards selection of the site to meet winter pavement data needs and not meteorological needs. It has only been a recent recognition that there may be more value to the maintenance community to view RWIS as a meteorological support system that aids the weather forecast process. Unfortunately, the legacy of the early RWIS site selections will be difficult to overcome as they most generally do not provide a good representation of weather and/or roadway conditions a short distance further along the road. These observations are often not flagged as to their lack of representativeness of the larger area and can become incorporated into analyses that misrepresent the remainder of the local area.

The uses of these data are also hindered in the lack of a centralized national distribution of RWIS data. Efforts to standardize the data are improving with the release of data standards (NTCIP-ESS) that will allow consistency in data formats and promote the transfer and exchange of data without proprietary software. The framework for a national clearinghouse of RWIS data has been established through the NOAA Forecast Systems Laboratory's Meteorological Assimilation Data Ingest System (MADIS). Already a number of state DOTs provide their RWIS data for distribution using MADIS; however, depending upon constraints imposed by individual state DOTs this information does not necessarily provide the full RWIS dataset.

As part of FHWA ITS efforts to improve the collection of highway and traffic information, new opportunities in roadway sensing technology are emerging with the use of automatic vehicle location (AVL) equipped probe vehicles. These probe vehicles were initially developed to provide state DOT decision makers with improved information on traffic and road conditions, but are now beginning to be deployed to provide in situ measurements of weather conditions. As limitations on near real-time communications of the information to a central database are resolved, the use of AVL-equipped probe vehicles will provide a valuable new resource in the weather efforts in roadway maintenance decision-making. Again, the pace of these advancements will predominantly lay with the state DOTs and their funding availability to adopt and deploy new sensing technologies. However, the ability to provide enhanced roadway weather decision support using such technologies will aid in state DOT funding decisions.

A more significant challenge will be associated with the use of modeling capabilities supporting safety on the highway system. It is expected that current atmospheric modeling efforts underway in both the research and operational realms will continue to improve both in spatial and temporal resolution. So too, improvements in data assimilation and the use of sophisticated statistical forecasting systems such as ensemble modeling are expected to increase our ability to provide short-range site-specific model-based forecasts. However, the need for roadway specific weather forecasts that reflect the features found from truck cab height down to the pavement surface (and below) are the focus areas needing attention. Present atmospheric models do well in the free atmosphere, but begin to suffer the further they move downward into the planetary boundary layer. The influence of land features and the horizontal and vertical thermal structure in the lower PBL and surface layer create difficulties in current modeling systems that will only become more challenging as the spatial grid dimensions diminish. As present research is exploring methods to mitigate these challenges, the natural evolution of atmospheric numerical models will continue to enhance our ability to address spatial variations near the surface. However, forecasting elements associated with pavement conditions such as roadway frost, snow drifting, and snow accumulation requires more detail of the land-surfaces (natural and manmade) adjacent to the roadway than are possible in current atmospheric models and planned in the near future. Also, a critical component is the ability to effectively model the pavement surface conditions. This is where the dominant influence on

highway safety becomes critical. It is important that we better understand what meteorological parameters predominantly affect conditions atop different types of pavement. In addition, an understanding is needed of the thermal and mass fluxes under and within the various paved structures. Further, traffic also appears to have a strong influence on pavement conditions both in a improving and worsening conditions. While it is important that we improve our understanding of the friction layer, we must also improve our understanding of the influence of the dynamics and thermodynamics on the “contaminant layer”.

This creates an opportunity to develop a roadway specific modeling system that incorporates the asymmetric dimensions of the roadway system with a structure defined to support perturbations induced by fine-scale surface features relevant to the roadway environment. Present modeling of conditions in the roadway system is based upon the conformance of coarser spatial model information onto the roadway environment. Having a prediction system designed to conform to the geometry of the roadway would permit hybrid computational fluid dynamic and atmospheric prediction systems to evolve. This roadway environment modeling system will promote the evolution of more sophisticated pavement condition models. The coupling of better in situ maintenance activity and roadway weather measurements from systems such as AVL with improved roadway weather modeling will enable a more descriptive assessment of site-specific road and weather information, which can be used to construct the sophisticated decision support systems needed by maintenance professionals and travelers.

Communication of Weather Information to Highway Decision Makers

The manner by which weather information is communicated to highway system decision makers in the maintenance community is not uniform across states. This is largely the result of each state having separate methods by which they can most effectively communicate with their personnel. While some states utilize telephone call lists for providing information, most have some form of Internet access to their weather information service provider. And while many states promote the access of this information by a broad range of their staff, some states still rely on a more centralized method of acquiring their information with the acquired information then passed along to other maintenance personnel through a tiered method of dissemination. Unfortunately, whichever method is utilized by a state DOT, there are often difficulties in ensuring that the weather information is appropriately assimilated in the DOT decision-making process. Similarly, conveying weather information to the traveling public can also be problematic when the information content is not consistent across various state DOT sources. The improvement of communications thus lies not only in the method of communication, but also the content of the message.

Achieving the goal of providing improved weather support for highway system decision makers largely depends upon providing the best method of communicating information with the least amount of ambiguity and with the greatest level of utility of the information. Emerging systems such as 511 and the federal Maintenance Decision Support System (MDSS) Functional Prototype and the multi-state pooled fund research MDSS initiatives are beginning to address ways to enhance the quality and context of information provided to end users of the highway system. The 511 Deployment Coalition has prepared a draft guideline for weather content that is being circulated for consideration by 511 weather content providers. Adoption of this guideline will assist in providing consistency in the information content as well as the method of access. The MDSS efforts are working to support alternative methods of integration of weather content within a maintenance operation. However progressive these systems are, at present they still require final interpretation of weather information by the user. Therefore, the goal of weather content providers should be to provide the greatest level of decision support without the need for extended analysis and interpretation by the end user. This is a daunting challenge, as it requires the weather content providers to integrate more effectively the

end users needs into the information service provided. The shift from providing “weather content” to providing “potential results from weather” promotes decision makers to focus on their area of expertise, which is not meteorology.

The reason for this paradigm shift in weather support services is a result of the background of the end users. The end users in surface transportation most generally do not have technical training or education in weather data content and interpretation, contrary to the user population within the aviation model often used for comparison. Hence, when maintenance personnel are supplied with weather data and forecast information, but not a statement regarding the potential impacts of the weather and they are still left with the challenge of making decisions that frequently require them to analyze and assess the meteorology content. Recent changes in maintenance weather forecasting product delivery through the use of probabilities and finer spatial and temporal scales has worked to minimize the maintenance user’s analysis and interpretation, but has not eliminated the process. Further, the use of local observations including weather satellite and radar imagery still supplants short-range forecasts with the interpretation being almost entirely made by maintenance personnel. Also, since most private sector weather information is now conveyed to end users through the Internet, this has made web surfing for additional weather content a common occurrence by end users leading to potential conflicting information and further local user analysis of meteorological conditions. Some state DOTs have responded to this situation by employing professional meteorologists on staff to assist with the processing and filtering of this information to assist maintenance decision making.

The efforts of MDSS are responding to this challenge by designing methods to convert weather information into response scenarios. These systems will provide support for strategic and tactical decision making by maintenance personnel with minimal overhead of meteorological interpretation. The development of cognition algorithms to assist the maintenance personnel in selecting the most appropriate scenario will lead to less reliance on weather interpretation and more focus on deciding the most appropriate treatment method. Further, as the ability to communicate with individuals within vehicles or to vehicles directly continues to improve, more emphasis will be placed on providing enhanced site-specific weather impact information further into both the maintenance and traveler’s vehicle. Eventually, weather-based decision information from these MDSS systems will be distributed directly to maintenance vehicles and incorporated into in-vehicle 511 traveler information systems in a manner that will further enhance roadway condition content.

Opportunities for and Barriers to Effective Application of Weather Information to Highway Safety and Operations

As the deployment of both the MDSS and 511 systems are largely private sector activities in support of state DOTs, the private sector must be actively involved in the evolution of the technology. This presents an opportunity for both the research effort and the diffusion of technology within the private sector. In particular, the relationships that have been fostered over the years between the state DOTs and their private sector weather service providers enable these private sector meteorologists to be effective interpreters of the state DOT needs and hence become an asset to the research community. This provides a tremendous opportunity for public-private-university partnerships to be fostered. Recognizing the surface transportation weather industry as knowledge experts will permit researchers to channel their efforts in an efficient manner towards the salient issues communicated to the private sector by state DOTs during years of support. These partnerships will also provide the formation of testbeds to not only evaluate the science and technology stemming from the research, but the efficacy of its adoption in the marketplace.

One misconception that does exist is that the private sector will not engage in research and development to further the technology in surface transportation weather. This potentially creates a barrier between research agencies and the private sector as it can promote a breakdown in communications on pertinent research agendas. While public and private research programs follow separate paradigms, they both address the same quest for new knowledge and technology. Mechanisms need to be established that foster the exchange of creative ideas through collaboration and partnerships. The use of private sector research funding vehicles such as the small business innovation research (SBIR) or the small business technology transfer (STTR) program should be a strong part of future federal research funding for surface transportation weather. Since the private sector has the responsibility to provide the best quality support to end users of the highway system, they must be motivated to embrace the latest technologies that will permit them to provide the highest quality service and information.

An important opportunity that exists is the creation of a national RWIS database that is openly exchanged nationwide as is done with other public domain weather data. The present MADIS efforts should be investigated to see what resources would be required to construct such a system and what resources are needed by state DOTs to foster their participation in such a system. As information systems extend across state borders, the need for seamless data sources is important to support both research and operations. One barrier to this is the number of legacy RWIS systems in existence that are not compliant with new NTCIP-ESS data standards. The upgrade of these systems is important, but will take time with the constraints of state DOT budgets.

Finally, an important barrier exists relating to human perceptions in both the surface transportation and atmospheric sciences communities. Within the surface transportation community there is a general lack of understanding of the capabilities and limitations of the weather community. This creates both a false sense of expectations with some while a level of frustrations exists with others that the weather community cannot deliver. Overcoming this confusion will require closer interactions and integration between the communities with cooperation in joint problem solving. Within the atmospheric sciences there is misconception that the same forecasting methods that are used for general forecasting and/or aviation meteorology can be adapted for surface transportation weather applications. It is important that surface transportation meteorology be developed with an identity that reflects the unique situations encountered along the roadway and that educational efforts be developed to prepare new meteorologists for careers within surface transportation weather research and operations.

Summary

There is a long thread of information processing and decision-making between the basic physical observations and the outcomes. Comprehensive research, development, and technology transfer involving both the research and operations sectors are needed to: 1) adapt weather information to transportation needs; 2) filter, fuse, and present information for human decision support; 3) tie operational practice to the best available information, and; 4) validate outcomes that are always a mix of many factors and decisions. A unified and targeted national research program can have significant benefit to the transportation outcomes, mostly by leveraging existing resources on behalf of transportation applications. However, the efforts of the private sector and state DOTs to embrace these research outcomes and effectively implement the technology advances are critical to realizing the expected outcomes of greater safety, security, mobility, and productivity. These are achieved by better weather information and decision support to those who maintain transportation facilities, plan trips (individual and commercial), manage traffic, plan facilities, or respond to emergencies.

Present and Near-Term Potential in Providing Weather Information to Improve the Highway System

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Fortunately, the other panelists are experts in meteorology and I am sure will cover topics such as modeling and observational data requirements much more thoroughly and accurately than I could hope to. Therefore, I would like to cover the topic from the aspect of technological factors of road weather information systems (RWIS), human factors and Intelligent Transportation Systems (ITS).

I am sure there is consensus that the more observations that are available and the more frequently they are collected, the better. There are over 2000 RWIS sites in North America including systems on over 130 airports. While some of these sites may be redundant with AWOS and ASOS sites, certainly there needs to be a consolidation of weather data from the various sources across the country. This should contribute to greater resolution of the models. However, this assumes that all observational data is of equal or similar quality and have equivalent representations of the collected measurements. Not all observations from RWIS sites are equal in their application to a particular forecasting model. RWIS systems do not have a national standard for location, equipment performance, and capabilities or data representations.

RWIS has traditionally been a low bid procurement process with system specifications varying from agency to agency. Consequently, the quality and accuracy of the meteorological equipment can vary from site to site. Pavement sensors, which have no standardization, can vary even more significantly from vendor to vendor and measured pavement temperatures can have significant differences between products and technologies such as between active and passive sensors. Active pavement sensors must generate heat to calculate the freeze point and consequently measure higher pavement temperatures than passive sensors. Additionally, chemical measurements and freeze point calculations also can vary from vendor to vendor with some vendors reporting only chemical factor (a relative measurement) while other provide freeze point based on the chemical used. For forecasting pavement freeze point, there is an additional critical measurement, the sub-surface temperature. Presently, the sub-temperature probe depths can vary from 8 to 24 inches based on procurement specifications or vendor standard practices.

There are two types of forecasts. There are forecasts for very site specific locations and a general forecast that applies to a much wider geographical area. Winter maintenance practices often require both types of forecasts for effective safety measures. However, these two different types of forecasts may require different environments for the meteorological equipment to be located in. The ability to segregate observations which provide value to each type of forecast will be an important step.

In the early RWIS years, many agencies deployed RWIS at sites that had the greatest preponderance to freezing and not to locations being representative of the areas meteorological conditions. For example, many RWIS systems were located in a dip in the road which would collect water and be susceptible to freezing or were located near a stand of trees which cast

shadows on the road and therefore had lower pavement temperatures. In some other cases, due to roadway beautification efforts, RWIS have been installed behind rock walls to be hidden from passing motorists. The meteorological data from these sites may have lower wind speeds and precipitation measurements due to the surrounding obstructions. For site specific forecasts, the location of the equipment was appropriate. However, to use these sites as representative of a larger area is not always accurate.

From nearly thirty years ago, before there was any contemplation of congregating data, RWIS sites were for the sole use of a particular agency. The agency could set up the data collection rates as frequently as they desired. This created a desire to have more “real time” data. For example, traditional RWIS sites measure the wind speed every second and display the wind speed and direction as the average over the last minute and wind gusts as the maximum speed over the last minute. The new NTCIP ESS standard and NWS uses two-minute averages for speed and direction, and the last ten minutes for wind gusts. Adding to the complexity are some agencies that combine both traditional RWIS measurements with NTCIP ESS methods and have them labeled as “vendor specific objects”. The complexity for forecasting is obvious. It is important to understand that the history of RWIS installations was less for wide area forecasting but increasing driver safety at very specific locations. If RWIS is to be used for nationwide forecasting models observational data, there should be a planned coordination for specific RWIS sites as well as those located to be more representative of the surrounding area.

Forecasting models will continue to improve and the communications technology to collect observational data will not only improve, but costs will continue to decrease. This will allow for data to be collected more frequently in the future. With a greater frequency of data collection and more powerful computing platforms, models will be able to run more often providing better quality forecasts. Until that time, the human remains an invaluable part of the forecasting process. Today, due to the limited data collection rates and the frequency at which models are run, a human observer watching the changing meteorology using radar and satellite imagery still remains the best form of quality assurance and the best method for forecasting near term weather events under rapidly changing or anomalous weather conditions. With anti-icing practices, the weather conditions six hours in advance are most important which allows for the preparation and deployment of the winter maintenance personnel and vehicles. Relatively few anti-icing practitioners today realize the limitations of present meteorology and the importance of how to interpret the forecasts. With labor, chemicals and other operational costs, a single winter event can cost over \$100,000 to a public agency. Every year, there are a number of situations when the decision to spend that \$100,000 is not clear cut and the agency must gamble on whether to deploy maintenance operations or not. Some agencies will deploy every time it snows, regardless of whether there is a possibility of freezing pavement. Few people would invest \$100,000 in real estate or the stock market without consulting with a realtor or stockbroker. I estimate that less than 30% of all RWIS equipment owners use pavement forecasts. Much less than 5% of all RWIS users consult with a meteorologist. Consultations with a meteorologist provide greater insight into the weather conditions, provide updated information and thus contribute to better maintenance operations. That so few agencies use pavement forecasts and consultations demonstrates an educational gap with many winter maintenance operators. Not understanding the value of forecasts and consultations is a more limiting factor to effective nationwide winter maintenance than the state of the art of forecasting models simply because a vast majority do not use pavement forecasts in their operations.

However, if we had a perfect weather forecast, do we have perfect processes? Whether an agency practices anti-icing or de-icing, the ability for a chemical to work effectively depends upon the ability for the road to hold and to retain that chemical. Chemical retention depends upon numerous road conditions such as road surface, road structure, road profile and road material, in conjunction with vehicle volume and vehicle speeds. Assuming road structure remains fixed from one winter event to the next, then the variables are time of chemical deployment, amount of chemical, vehicle speeds and vehicle volumes. The faster cars travel and the more vehicles there are, the greater the amount of chemical, which is splashed into the air or onto the shoulder of the roads. Vehicle detection systems can be used with RWIS and data could be correlated to measure the effects of vehicle to chemical retention. Possibly, RWIS systems need to be outfitted to measure “splash” as well. The other difficulty for anti-icing is that both passive and active sensors do not measure the amount of de-icing chemical. The measurement of freeze point is based on the percentage concentration of the chemical. Therefore, in anti-icing operations, whether 500 gallons or one gallon of 20% salt brine is deposited on the same stretch of roadway, the measured freeze point is the same prior to precipitation. For effective anti-icing operations, a measurement of the amount of chemical retained on the roadway would be useful. Today, this type of sensor is not available.

Highway system decision makers are typically from Maintenance, Traffic, or Operations. The other decision makers are the users of the highway system, the driving public. Depending on the information each requires, the communication media is different. Pavement forecasts are delivered today via the Internet, fax, pagers and cell phones. From an Intelligent Transportation Systems (ITS) perspective there has been a movement to providing weather data over a variety of mediums like the Internet and 511 telephone systems. However, I believe there needs to be a greater coupling between maintenance operations and ITS. For example, within ITS, many transit authorities track buses with transponders or GPS systems so that they know where the bus is on the route and then provide customers at the bus stops information on exactly when the bus will arrive. Also, almost every transit authority publishes their bus schedule on the Internet. As a driver, I always feel relieved if I am driving on the road after the snowplows have cleared the road. It would be useful to have snow clearance routes published on the Internet with real time snowplow location information. One of the barriers to effective winter maintenance is vehicle congestion which blocks the roads and prevents the snowplows from accomplishing their task. If drivers knew when the roads were cleared, they may wait at their offices or homes until after the plowing and there would be fewer cars congesting the snow routes. Another lesson from transit authorities is the use signal prioritization, a system where buses communicate to the upcoming traffic signal to change the signal to green. The City of Los Angeles has outfitted their transit buses with transponders located on the bottom of the buses. The inductive loops in the road read the transponder and alter the traffic signal timing upstream of the bus. Obviously, since snowplows are most effective when they are moving, this type of prioritization increases their effectiveness.

Another ITS tool is ramp metering systems. Ramp metering regulates the volume of vehicles entering the freeway network to reduce congestion. Many of the algorithms which, regulate the number of vehicles, are based on lane occupancy, volume and speed or a combination of these parameters. Empirical data has shown that weather events can reduce the capacity of the roadways by 25% or more since drivers increase follow distances and slow down. Driving on a snow-laden road has different characteristics from a dry road and new ramp meter algorithms for varying weather conditions need to be developed. In conjunction with Ramp Metering, there is

an application for variable speed limit signs. In England and other parts of Europe, based on traffic conditions, different speed limits are posted on the highways and very strictly enforced using radar guns and CCTV cameras which automatically generate speeding tickets for violators. The posted speeds are calculated to allow traffic to constantly move and prevent stop and go traffic conditions. Reducing “stop and go” congestion during winter conditions will reduce accidents on slippery roads.

Safety on our highways is a combination of effective maintenance measures, chemicals, forecasts and equipment. But the most important is proper driving behavior and equipment. At a recent luncheon a General Motors (GM) scientist spoke about research in human factors and driver behavior. He found that in foggy and low visibility conditions, drivers would actually accelerate to reduce the distance between themselves and the vehicle in front until they could see the preceding vehicle’s taillights. Once attaining this position they would maintain that follow distance. Therefore, as the visibility worsened, the distance between vehicles was reduced. This behavior obviously reduces the ability to stop in time and may be the underlying cause to many of the multiple car accidents in foggy weather. If this is true, cars with adjustable taillights, which can be made brighter, could reduce these types of accidents. For example, many cars have fog lights in front, but taillights could be designed to also brighten when the front fog lights are turned on. A recent development in automotive technology will also improve driver safety in these conditions. Light emitting diodes (LEDs) are being increasingly used for brake lights and are replacing incandescent bulbs. LEDs illuminate much more quickly than incandescent bulbs and at highway speeds, the difference in illumination time can equate to approximately 40 feet, or several car lengths. However, at the core, better driver training and awareness is critical. The same GM researcher also found that in normal conditions, drivers have a tendency to stay far enough behind the vehicle in front to be able to see the entire rear of the vehicle and some of the roadway between the vehicles. For sedans, the follow distance was relatively uniform. However, with SUV’s, the drivers are sitting higher up and can see more of the vehicle in front as well as the pavement and therefore have a greater tendency to tailgate. So not only are some SUV drivers over confident in winter conditions, they are also following at more dangerous distances.

If we assume that better forecasts are the start of the chain for better winter maintenance practices for safer highways and roadways, then every link of the chain from this first link needs to be improved. Over time, the forecasting models and the requisite observational data will improve but first will require more sites and better standardization. Then, maintenance personnel will only utilize better forecasts if they are educated to their importance and applicability. Next, real time maintenance activities and information should be relayed to the public so that they can make better decisions on when to leave their homes and offices. Then once on the roads, the driving public needs increased education of dangerous driving habits that can have catastrophic effects.