THE FEDERAL PROGRAM IN THE UNITED STATES FOR ROAD WEATHER MANAGEMENT

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1. Abstract

In the United States, the Federal Highway Administration (FHWA) oversees federal-aid funding, standards and research for highways. Since the FHWA builds and operates no highways, it leads a partnership with states and other highway operators in all its programs. This has created a challenge to creating a coordinated road weather research program, and in bringing highway constituencies into a weather information program that is operated primarily by other federal agencies.

The Road Weather Management Program within the FHWA derives from the Intelligent Transportation System (ITS) program under the U.S. Department of Transportation (USDOT). The Road Weather Management Program began in 1997 to coordinate various weather-related activities within the FHWA, and identified environmental information for decision support as a significant need, along with further development of winter road maintenance treatment practices. In 1999 the Program was formalized when the FHWA first created an operations unit. The Program continues a long-term project to document decision support requirements involving weather and road-surface environmental conditions for winter road maintenance, traffic management, emergency response, and traveler information. The requirements are the initial part of prototype-development and operational-test phases.

At present, the Program has nearly completed a three-year evaluation of its first operational test, called FORETELL™, involving meso-scaled weather modeling, road surface condition prediction and information to operators and travelers. A second generation of decision support components has been developed under a program involving several federal research laboratories and is proceeding to operational testing. Results are coming in from university research projects on road weather observation and prediction. Coordination with other federal agencies, especially the National Weather Service, has strengthened the national efforts on services to surface transportation. The National ITS Architecture and ITS standards have been strengthened regarding environmental information and maintenance decision support. This paper summarizes the Program and significant results that have been obtained in the last two years on requirements, technology applications and the organization of road weather services in a decentralized, public and private, system.

2. Introduction

The ITS program of the USDOT was formalized by the authorization of an ITS research program in the 1991 Intermodal Surface Transportation Efficiency Act. This can be said to be the start of a focus on operations within the FHWA, as opposed to its traditional construction-grants program to the states. Such a focus was necessary to high-level recognition of weather impacts on highways, other than climatic effects on facility design and location. Unfortunately, the ITS program itself gave only secondary consideration to weather, since weather information sources were defined as external to the ITS. Under the circumstances, the FHWA interest in weather and its effects on road operations was, for a long time, scattered and at a low level. Most of that interest concerned winter road maintenance, and various projects on road condition measurement, snow removal and ice treatment, go back decades.

The Road Weather Management Program was created in 1999 to bring together the FHWA efforts to improve highway performance under weather threats through information systems and operational techniques. The program originated in the formation of a FHWA Weather Team out of the rural ITS program in 1997. Both authors were involved in forming that Team. In 1999 a reorganization of the FHWA created the first operations unit, just below the Administrator level, that encompasses both the ITS Joint Program Office and the Office of Transportation Operations where the Road Weather Management Program now resides. This has created the organizational mandate to take a comprehensive approach to weather in highway transportation, while maintaining intermodal links through the ITS program. The Road Weather Management Program also encompasses research activities under the Highway Research unit. The Program can therefore look back on four years of progress toward its goal of improved highway performance through information systems and operational techniques, and forward over its 5-year plan.

3. The Key Issues

The approach of the Program has been to survey all surface transportation needs with respect to weather threats and then successively focus on sets of needs along development tracks that perform necessary research leading to deployment. Needs are defined as the decisions that activate highway operations or use. The decisions are between an information system for decision support, and the operational techniques that affect the physical highway system. The decision maker is central, and the decision maker embodies the goals of improved highway safety, mobility, productivity and environmental quality. Requirements are then levied on the information system and the operational techniques together. The requirements have been documented through the Surface Transportation Weather Decision Support Requirements (STWDSR) project and the requirements drive each development track. The STWDSR documents may be found at www.its.dot.gov/welcome.htm by searching on that title.

Initial focus was on winter road maintenance needs. The stakeholders for these needs are considered to be the highway maintenance managers, as decision support users, road-weather researchers, developers of decision support systems, and the private vendors who ultimately will be providing the information systems within the ITS. Work with these stakeholders goes back to a symposium under the Weather Team in 1997. The latest meeting of the group, in June of 2001, attracted 73 people. These included representatives from 20 state DOTs, 18 system developers, and six federal and academic-consortium laboratories. The latter group, referred to as the "national labs" includes three laboratories under the National Oceanographic and Atmospheric Administration (NOAA), two Department of Defense laboratories, and the National Center for Atmospheric Research operated by the University Consortium for Atmospheric Research. The reasons for maintaining this diverse, public and private, group are to moderate the limitations of purely proprietary development, and to bridge the divide between the public services of the National Weather Service (NWS) and private value added meteorological services (VAMS). The VAMS also dominate the market for environmental sensor station (ESS) observations and road-weather information services (RWIS). The objective is to develop the market for ESS and RWIS by better documentation of user needs, an open information system within the National ITS Architecture and standards, and more sharing of research. The VAMS will still be providing systems and services, and it is policy that private developers retain rights to sell their products commercially even when developed with public participation.

The 1997 symposium identified issues captured in a 1998 White Paper. It was found that most of the State DOT users focused on the quality of weather information. But that information is outside of ITS and FHWA responsibility and is only part of the need. Weather is one factor that creates the physical road conditions that threaten performance, but there is a gap of geophysics and scale that separate weather from the road conditions. Further, the point is not just to know the threat, but to do something about it, and that requires fusion of information on the threat, the state of the highway systems, and the state of any resources used to treat the threat. Decision support that fuses all three types of information and presents them to improve the activation of treatment techniques was the missing link that was fully within the FHWA and ITS domain.

The STWDSR documents have emphasized the scale of decisions from the start. This has become a key principle in allocating requirements and development efforts. The table below shows the scale categories used to classify decisions and the information to support them.

Table 1: Scale Definitions

Scales	**Time Horizon** **Functions**	**Corresponding Weather Scale**	**Winter Road Maintenance Example**
Planning	months + Provides resources.	Climatic	Buying equipment or chemical stocks; Hiring and training staff.
Operational	hours to days Manages the deployment of resources.	Synoptic/meso	Calling up crews, readying vehicles, dispatching treatment beats.
Warning	sub-seconds to minutes Operates the resources.	Micro	Operating a treatment vehicle (snow plow and spreader); Control of automatic equipment.

Three scales were defined to relate to the decisions: planning, operational and warning. These correspond to weather scales, although the operational scale spans the synoptic and meso weather scales. The great challenge in the production of geophysical (weather *and* road-condition) predictions has been to move from the synoptic scale to fine-meso (also called "miso") scales in order to characterize the diversity of road conditions over kilometer resolutions.

The spatial scale of the geophysical information is related to the time horizon of decisions. The time horizon determines the feasible predictive accuracy and hence the *effective* spatial resolution according to the overlap of the error bounds at adjacent points. The STWDSR project emphasized the capture of time leads for the types of decisions. In the case of winter road maintenance management, all in the operational scale, 53 different decision types were found (refer to the STWDSR version 2.0 documents). The maximum time lead may be as much as 100 hours before a weather event, but 48 hours down to one hour is taken as typical. Managers do relate the time lead to the confidence of their decisions and expect longer leads to mean more uncertainty. Still, there is great dissatisfaction with the perceived unreliability of predictions. This has been identified as a lack of quantitative risk information in the predictions, and the lack of formal risk-decision making by the managers. However, most managers cannot manually make use of the risk information and this becomes one of the challenges for better decision support.

Decision support is created by decision and user-specific applications within the ITS. But an open system of transportation and geophysical information must feed decision support. Therefore the basic problem divides into creating the applications that interface with the human decision makers directly, and making available the environmental, transportation and resource information from observation and predictive processing. It has been important for the Program to pick targets within these problems carefully, because of its own limited resources. At the federal level, only about $2.5 million a year has been available for research projects, and there are only about 4 staff (federal and support) dedicated to the Program.

4. Development Tracks

The Road Weather Management Program establishes development tracks for decision support to sets of needs, or for cross-cutting issues. A track goes through a development cycle from research, to operational test, to deployment. Presently, the Program is on its second track for winter road maintenance, has launched a track on ESS/road-condition prediction, and is beginning tracks for traffic management and emergency management decisions.

The first development track is considered to be the Foretell project, launched as an operational test in 1997 and involving the State DOTs in Iowa, Missouri and Wisconsin, and a private developer, Castle Rock Systems. Foretell became operational over the winter of 2001 and is under a three-year independent evaluation. Further information is on the Road Weather Management Program website at www.ops.fhwa.dot.gov/weather/ .

The second track has been named the Maintenance Decision Support System (MDSS) and follows formal requirements developed in the STWDSR. This MDSS project involves the entire stakeholder group. The national labs are creating the MDSS prototype that will go into demonstration testing in 2003. The MDSS emphasizes the key requirements identified in the STWDSR Operational Concept Definition, namely the fusion of different information sources and the presentation to users, in one application with a graphical user interface (GUI), of the information that directly supports an operational decision. This emphasizes what treatment actions to launch, not just the weather threat. The MDSS is further described in the MDSS Project Plan found at the Program website. The figure below is a schematic of the MDSS.

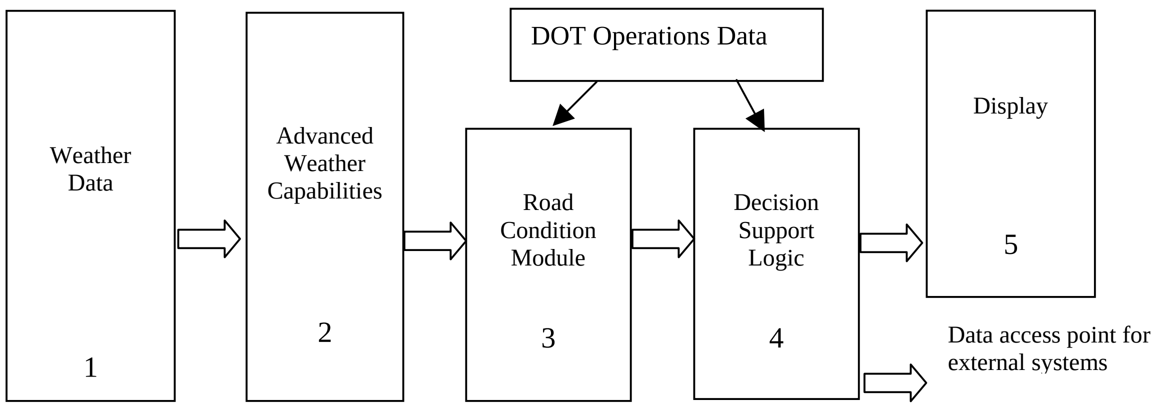

Figure 1: MDSS Schematic Diagram

The Advanced Weather Capabilities in module 2 feature adaptive learning in the fusion of multiple weather and road condition prediction sources. A similar process is being developed for the Road Condition Module 3. Further, numerical weather prediction ensembles are being demonstrated in the Weather Data module 1. The key results are that: 1) multiple prediction processes can be used, in an open system, 2) quantitative risk information is generated as part of the fusion process, and 3) the best predictors are identified over time through their weighting against observed results. This ultimately enables formal risk decision algorithms in the Decision Support Logic module 4. A remaining challenge is the appropriate user interface in the Display module 5.

In 2001, the Program also funded five university/NWS/DOT partnerships through the Cooperative Program for Operational Meteorology, Education and Training (COMET). This was the first time that State DOTs had been added to the COMET partnerships. The projects are to research aspects of Environmental Sensor Station (ESS) investment and its relation to road condition forecasting. The collaborative efforts include building better relations for training and information between the meteorological and transportation agencies. The research projects will continue through 2003.

The COMET projects are the research step to support better guidance on ESS deployment, data collection and processing. At present there are about 1200 ESS sites across the U.S. These are too few to observe road conditions adequately, and their expense requires criteria for efficient siting. But the benefit of ESS deployment has to be measured in the ultimate improvement of decision support and highway performance through treatment and traveler information. In the long chain from observation, through prediction, to decision support and performance, it is not clear where the points of most efficient investment lie. For road temperature, that the ESS alone measure, there are three related methods of prediction: time series filtering of the point observations, thermal mapping to correlate observed with other points, and heat balance methods over weather-prediction areas. Further, there are potential tradeoffs between the in situ measurenments of the ESS, mobile sensing and remote sensing, especially as the technology for the latter progresses. At present, there is no comprehensive analysis to indicate an efficient deployment of the ESS, but it is hoped that the COMET projects will contribute to such an analysis, and to better use of any ESS observations.

Another ESS issue is that the current system design is not open. The data are often retained by the vendors and their formats are proprietary. The observational system in the U.S., including many other types of surface sensors, is fragmented. A goal is to have all geophysical observations openly available to use in further prediction processes, including national assimilation for NWS use. This does not preclude sensor owners from charging for their data (as is the case now with lightning data used by the NWS), but it does require the open system standards and connectivity. Progress is being made by regional "mesonets" that collect and use data from a variety of sensors, but a national system is not yet present. Assimilation of the data means more than just having observations available, it is a statistical cross-comparison of data that produces quality control on individual observations while preparing them for further numerical modeling. Assimilation is best accomplished with the most comprehensive datasets over a region, and using both meteorological and road-condition observations. It is a Program objective to make this happen in concert with national and regional NWS offices.

The payoff of any development track is deployment. The FHWA will not supply or operate systems. Deployment is up to private vendors and their customers, whether public highway agencies or private highway users. Beyond research and development, the FHWA does support outreach and training, primarily to the state and local highway operators. In concert with the Program planning, best management practices in operational techniques are assessed and the state of the art in information systems is monitored. The Program funds training efforts and compiles case studies on model capabilities. Operational test evaluation of the development tracks has been funded separately by the ITS program and is a major contributor to identifying effective operational techniques and systems solutions.

5. Future Plans

The Road Weather Management Program is initiating further development tracks, is involved in improving the representation of weather /road condition information in the National ITS Architecture, and is pursuing a dedicated road weather applications research program in the next surface transportation authorization.

The development tracks will be expanded from maintenance management (MM) to traffic management (TM), emergency management (EM), and traveler information related to those management decisions. The vision is to create greater integration between the management functions, and to make use of the increasing capabilities of ITS in directing highway users for operational management of the system under congestion, facility outages, or disasters related to weather. This kind of integration of course goes well beyond a weather interest, and requires the system coordination provided by the National ITS Architecture. The full architecture may be accessed at www.iteris.com/itsarch/ .

Traffic management in the U.S. encompasses traffic control, traveler information related to highway use and management of highway incidents. Emergency management has many facets, and it is first being approached through the management of hurricane disasters where traffic management plays a role in evacuation, reentry, and support of emergency response units. Maintenance management also plays a role in highway incident response and recovery.

The dominant management of any kind of incident, whether terrorism, weather disaster, toxic release or highway crash, is *not* by the highway operators. An Incident Management System (IMS) is being defined that allocates roles and provides coordination between emergency managers, police, fire response, emergency medical response, the military, and logistics managers that include highway operators. In the case of hurricane disaster management, state and county emergency coordinators activate and manage the various response resources.

Historically, the emergency coordinators have been prepared for much wider-area activities than highway operators, and the FHWA has been secondary to the national role of the Federal Emergency Management Agency (FEMA). The challenge is to interface the developing Intelligent Transportation System with the Incident Management System , and to use the inter-state integration of the ITS to make highway operators more valuable to hurricane and other disaster management. Scale enters as a factor in how disaster management responsibilities are allocated. With limited reach of highway surveillance and communications for traffic management, usually not beyond metropolitan areas, it is not possible now to allocate traffic management a substantial role in evacuation and other large-scale traffic movements.

A nationally integrated ITS must have comprehensive road condition monitoring, of weather-related and traffic conditions. There are 4 million route miles of public roads in the U.S., but about half of all vehicle miles are carried on just the 160,000 route miles of the National Highway System (NHS), consisting mainly of the freeways and primary arterials. A recent initiative of the FHWA is to define a NHS information infrastructure as the desirable surveillance and communications equipage of the NHS. The Road Weather Management Program is active in the work to specify the ESS and other weather observation components of this infrastructure. That will be a culmination of the ESS research track already underway. Work on integrating a regional system as part of the hurricane disaster management track will be part of the infrastructure definition and testing. When surface weather observations and related road conditions are an integral part of the NHS, highway operators will also be prepared to make a bigger contribution to the national weather information infrastructure. This in turn will improve the ability to forecast weather-related road conditions.

The interest of the Road Weather Management Program is to see that weather and its highway effects are adequately considered in any ITS deployment. The integration and reach of the ITS, its interfaces with incident management systems, and its interfaces with weather information, all rely on the systems-development context of the National ITS Architecture. The National ITS Architecture has been in development for nearly 10 years, and is based on the needs defined in user services. The user services are oriented toward the kinds of decisions made. Traffic management has long been emphasized, and emergency management is represented, but maintenance management has only recently been included by the adoption of the Maintenance and Construction Operations user service in 2001. There is no “road weather” user service because that is not by itself a decision set for surface transportation. Weather information affects most user services, but is concentrated in none, and that has been a reason why weather and its dependent road-condition information has not been a focus in the National ITS Architecture before now.

The strong advocacy group for ITS in the U.S. is ITS America. ITS America is a partnership of federal, local, academic and private interests. ITS America created the original ITS Strategic Plan in 1992 and is working on the strategic plan for the next 10 years. Within ITS America is the Weather Information Applications Task Force. The Road Weather Management Program has been active with this task force in elevating weather issues in the ITS program generally and in the National ITS Architecture specifically. Since the task force includes Canadian representation, the work done in the Canadian ITS Architecture has contributed useful approaches to treating the weather and road-weather informatioin flows. As part of the Maintenance and Construction Operations user service, but hopefully more generally, it is expected that the National ITS Architecture will be modified to better represent the use of weather information, and the production of related road-condition information throughout the ITS. That includes a better distinction between weather information, that will mostly be produced outside the ITS, and the road-condition information that will mostly be within the ITS domain. Eventually, requirements work such as the STWDSR, that has already contributed to the user service, should be extended to all user services.

Perhaps the most important future target of the Program is the surface transportation reauthorization, due from the Congress in 2004. The funding of the Program to date has come mostly from the ITS research in the current authorization, and it is not possible to increase the Program substantially under the current authorization. There is no reason why the activities of the Program cannot also be funded in partnership with the State DOTs who have federal-aid research funds to allocate. There are pooled-fund projects among states, notably under the AURORA consortium that is devoted to winter road maintenance and other weather-related projects. However, the voluntary constributions of states to these programs is smaller than the current direct-federal funding.

It is the goal of the Program to have a dedicated road weather applications research program in the next authorization. For comparison, applied aviation weather research under the Federal Aviation Administration (FAA) has been budgeted for $30 million in 2001, or more than 10 times the FHWA budget for applied road weather research. A key difference is that the FAA is the airspace operator, and can better centralize research and systems development. While a road weather research program must necessarily be a federal-local, public-private partnership, its funding needs are no less. Some FHWA leadership will be needed to coordinate research agendas, mobilize the national research talent, and perform the interfederal coordination with the National Weather Service, the Federal Aviation Administration, the military and others. The FHWA already is active with the Office of the Federal Coordiunator of Meteorology (OFCM) that is established for such inter-federal coordination. This Office, just in the last two years has also elevated surface transportation in its priorities.

The American Meteorological Society has been another important partner in the effort to make surface transportation weather a national priority. The effort for a dedicated research program was kicked off by a session jointly sponsored by the American Meteorological Society, the Office of the Federal Coordinator for Meteorology, and the FHWA at the 2001 ITS America Meeting. Interest increases, and hopefully the funding will follow.

6. Conclusion

The U.S. has a decentralized system of highway management. Weather information however has a very strong national component in the National Weather Service, an agency with strong partners in the Federal Aviation Administration and the military. This has kept the focus of weather information in the air and over the seas. It is ironic that despite the vast and apparent effects of weather on surface transportation, only recently has that mode become a significant factor in a broader program of geophysical information. A large part of the reason for this progress is the ITS and the Road Weather Management Program within the FHWA that has directed the ITS in road weather issues. The U.S. is, perhaps, behind other nations in its development of winter road maintenance applications because of the former diffuseness of interests. Addressing that and other weather-related road management issues is a matter of harnessing the available research resources and deploying an integrated ITS. It is expected that in the next ten years there will be a vastly more effective system to respond to weather threats in all of surface transportation. A dedicated national, surface transportation weather-applications research program will more than pay for itself in the reduction of highway crashes, delays and lost productivity.