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Improving the Safety, Efficiency and Capacity of the Highway System by Improving the Use of Weather Information

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1 INTRODUCTION

The U.S. public, and more specifically its economy, are highly dependent on the national highway system. More than 200 million cars and trucks use the national highway system and critical parts function at or near their maximum capacity much of the time (OFCM, 2003). Weather reduces capacity and significantly impacts efficiency. Weather is often the catalyst for triggering congestion, particularly for roads operating near capacity.

Weather also plays a critical role in highway safety. In the U.S. each year, approximately 7,000 highway deaths and 800,000 injuries are associated with poor weather related driving conditions. The economic toll of these deaths and injuries is estimated at $42B per year (Lombardo, 2000). Weather plays a role in about 28% of the total crashes and 19% of the total fatalities. No matter how the statistics are presented, the societal and economic impact of adverse weather on the highway system is huge.

Travelers are quite aware of the impact of weather on the roadway system. A Gallup public opinion poll conducted in 2002 indicated that 40% of the potential users of a national "511" system identified weather as the most important information element (ITSA 2002). An excellent example of the use of tailored weather information for roadways is the use of Road Weather Information Systems (RWIS). RWIS has been successfully deployed in 47 states, primarily to support winter deicing and anti-icing operations. Case studies have shown that material and labor costs can be reduced significantly by proactively using current and predicted weather and road condition information from RWIS (FHWA, 2002). A Finnish study concluded that road weather information services had a cost-benefit ratio of 1 to 5 for snow and ice control (DOT 2002). This ratio was supported by a similar study in Washington State (Boon and Cluett, 2002).

So, given the enormous impact weather has on the highway system, its impact on safety, capacity and efficiency, and the potentially huge benefits that could be realized if weather information was used more effectively by road operating agencies and the public, why has it not received the attention it deserves? What has or has not been done to promote surface transportation weather, what opportunities are emerging, and what impediments are in place that have impacted progress to date? What policies, if any, are needed at the federal and/or state levels?

In order for the weather-transportation community to begin answering these questions, this paper will give an overview of characteristics of an effective road weather research program and several policy issues (intra-federal coordination; federal, state and local coordination; and public-private-academic coordination).

2 OVERALL CHALLENGES FACING ROAD OPERATING AGENCIES

One significant challenge for state and local governments is maintaining a workforce that can respond to weather threats in the most efficient and effective manner possible. The main threat to the 34 Snow Belt states is responding to winter weather and the disruption it brings to safety and mobility of people, goods and services. The workforce is aging and a significant number of retirements are expected in the next decade resulting in a loss of experience in dealing with weather threats. Extensive weather training and road weather decision support systems are needed to address this reality.

Another significant challenge is related to how the public and our economy have become ever more dependent on the highway system. The motoring public demands passable roadways everyday no matter what the weather brings. Many goods and services are based on just-in-time delivery, so disruption in mobility can cause considerable negative economic impact. Politicians responding to the people they represent call for fewer government workers and tighter budgets meaning government must respond to winter weather with the most efficient and effective operational strategy possible. The motoring public needs to accept some responsibility in meeting their needs for increased mobility and safety. Road and weather forecasts need to be provided to the public in an understandable and uniform format. Map symbols and colors need to be uniform across the United States. This information needs to be disseminated in a manner that has high public interest. Road condition reports and appropriate driver response needs to be part of driver education programs.

In the past decade, federal and state agencies have made tremendous strides in improving the efficiency and effectiveness of snow and ice control operations as a result of the findings of the Strategic Highway Research Program that ended in 1993. The findings of the Road Weather Information System's (RWIS) research and the proactive measures of the anti-icing research have revolutionized the way the maintenance community responds to the perils of winter weather. This has resulted in:

- A new generation of snow and ice control equipment being developed and marketed
- New chemicals being developed and marketed that are more environmentally friendly and have improved eutectic properties
- New training programs being developed to raise the knowledge and skill levels of operators and supervisors

Accurate weather forecasts, particularly precipitation, temperature and wind, and pavement temperature forecasts are key to the successful implementation of this technology. In Japan, driver training includes demonstrated proficiency on snow-covered roadways. The Japanese also provide detailed road condition and visibility reports in their rest areas. Japanese traffic management centers set the speed limits on variable message signs based on road conditions and existing and forecasted weather. Northern Europe has also invested significant resources in road weather. Weather and road condition sensor networks are expanding and advanced snow and ice prediction systems based on these networks are being implemented. These and similar technologies have been slow to arrive in the U.S. as the investment in road weather systems has been lower than in Europe and Japan.

3 CHARACTERISTICS OF AN EFFECTIVE ROAD WEATHER RESEARCH PROGRAM

A critical element of any applied research and development program is to involve the end users from the beginning. The decisions made by the end users must be addressed by the resulting technology and the products must be tailored to meet their specific needs. User needs should drive the research and the design of the solution. Too often we find solutions looking for a problem or a suite of predefined products being sold as the appropriate solution. In many instances, end users, who are not likely to be meteorologists, are required to interpret weather data and draw conclusions as part of their decision process.

One of the actions taken by the FAA to improve aviation safety was to develop a focused aviation weather research, development and implementation program. Because of its success in meeting the needs of the end users, the FAA windshear program grew and broadened to become the FAA Aviation Weather Research Program (AWRP). Although the total number of weather related accidents and deaths in the aviation sector are far fewer than the highway sector, the AWRP budget has grown to approximately $25M per year since its inception around 1993. The AWRP accounts for approximately 94% of all DOT weather research. The FHWA weather research budget is only $2.5M. Is there a need for a larger investment given the accident statistics and potential economic benefits of improved road weather information? What type of programs could or should be developed to address road weather issues and how should these programs be designed and implemented to ensure success?

The Vision of a Successful National Road Weather System

The FHWA Office of Operations' slogan is "21st Century Operations using 21st Century Technology."

With respect to weather, this means:

- Enabling transportation managers to implement effective strategies (advisory, treatment or control strategies) in preparation for (or during) any type of road weather event, whether it's rain, snow, ice, fog, high winds, high water or slick pavement.
- Providing travelers with route-specific information that describes road and weather conditions along their trip, i.e., anytime, anywhere road weather information.

To achieve these practices, detailed (high resolution, at the surface), tailored weather products linked to the road network and its traffic are required. It should also include both current and predicted conditions. To meet these needs, a broad, organized, well-managed program to improve the application of road weather services is needed. How will we get there and what policies are needed? How do we create an interdisciplinary program involving public, private, and academic sectors?

Another important program element is the process of exploring the art-of-the-possible through rapid prototyping. In many cases, the users do not know what is technically possible. This problem is particularly bad in the weather arena because the vast majority of people see the meteorological community through the eyes of their local television weather personality. Furthermore, the NWS forecasts are, by design, tailored for the general public so it is very difficult for a specialist in any user sector to imagine how advanced weather information technologies could be applied to their problem. A road weather research program needs to include a rapid prototyping component, and a long-term relationship with the end users must be established. This requires patience and long-term commitment by the sponsor since it can take a lot of time (several years) to engage the end users, gain their trust, and develop a satisfactory solution that fully addresses their needs, which, of course change with time. The rapid prototyping process allows solutions to evolve as the end user's decision-making paradigm changes. Prototype systems also provide an effective platform for exploring the benefits of various design approaches. Because the states operate the roads, each state will have its own special requirements so tailoring will be required.

A significant goal of government-funded research is to ensure that the results of the research get implemented for the good of the public. The mechanisms used to transfer information and technologies vary greatly and range from publishing research to delivering turnkey solutions to end user organizations. The FAA AWRP, for example, utilizes several technology transfer strategies including document publication, delivery of specifications and prototype software, technology commercialization through the private sector, and direct implementation of new technologies into FAA and NWS facilities. The FHWA Road Weather Management Program uses a complementary approach. It has structured its Maintenance Decision Support System (MDSS) program as a public-private partnership, whereby new technologies are prototyped and the resulting technologies (code, specifications, etc.) are openly distributed on request to any interested party on a non-exclusive basis. This structure is required because the highway systems are operated by the states, not the FHWA, and any new technologies must be implemented by the state DOTs or purchased as a service from the private sector or other third party organization.

Training and education must also accompany any technology development program. The surface transportation user community is not well versed on weather technologies and the potential benefit of proactively integrating advanced weather products in their decision process. There is also a high staff turnover rate at the state DOTs and this is expected to worsen as the baby boomers retire. In the road operations and maintenance arena, experience is critical.

In summary, an effective road weather research, development, and implementation program requires:

- awareness and advocacy building;
- end-user involvement;
- end-user directed research and development;
- rapid prototyping;
- long-term commitment;
- open development processes;
- technology transfer mechanisms; and
- education and training

If one were to analyze the FAA AWRP, one will find that all these components are present. It would not be a stretch to suggest that the inclusion of these program characteristics is a major reason why the program has been successful and well supported by the aviation community. What can be learned from the AWRP? Is it well known and respected within other segments of the DOT? Would it make sense to consider it a model for building a road weather research program? What are the major differences between FAA operations and the FHWA that would impact how a road weather research program should be established?

Because of the diversity of end users, complexity of operation, distributed administration (state DOTs), and specialized requirements for weather information, the annual investment required to address road weather will probably need to be on the same order of magnitude as the aviation weather program. A doubling of the weather program budget within the DOT would certainly raise some concern and generate a lot of tough questions. What approaches, dialogues, or options should be considered that could mitigate these concerns?

4 INTRA-FEDERAL COORDINATON ISSUES

How could a road weather research program be structured within the U.S. DOT, how does it link to the U.S. DOC, and who should take the lead?

The establishment of a surface transportation road weather research program designed to improve the implementation of weather technologies and services will pose some challenges and require a significant amount of coordination between federal agencies. There are already some gray areas when it comes to weather research and the provision of weather services. Misunderstandings could be exacerbated if the roles of all participants are not clear from the beginning. It is particularly important to include the private sector providers in the dialog since they are mainly responsible for providing tailored weather services to the state DOTs. One must remember that the NWS mission does not include the provision of specialized weather services to road operating agencies and that the FHWA does not operate any roadways. Because of these two critical factors, a paradigm much different from the way the FAA and NWS provide aviation weather services must be considered.

One of the biggest challenges may be educating and convincing the U.S. DOT that a road weather initiative is needed given their large investment in aviation weather services, and that surface transportation weather issues are significantly different from those of aviation. A united front consisting of federal agencies must include support from stakeholder groups such as the AASHTO, TRB, ITSA, etc. It is also critical that the management team from the FAA AWRP be involved in the advocacy building efforts so they can communicate the successes of their program, identify leveraging opportunities and at the same time remind U.S. DOT management that the problems the FAA are addressing for their end users are quite different from those of the surface transportation community.

The aviation weather program is focused on in-flight icing, windshear, turbulence, aircraft deicing, oceanic weather hazards, jet stream winds, and thunderstorm hazards. Whereas aviation weather focuses on airport weather and along a route of flight at a particular altitude, surface transportation weather issues focus on what is happening on the ground and at driver level and includes its impact on the road, rail or transit operations. In order to maintain mission critical efforts, the surface transportation road weather initiative should not be built at the expense of FAA weather programs. .

It is imperative that any new surface transportation road weather research program be viewed as an initiative that will ultimately benefit all transportation modes and is able to leverage investments made by each of the contributing administrations. At the current time, the biggest contributor to transportation weather is the FAA followed by the FHWA and FRA. If other administrations such as the FTA, MARAD, RSPA, were brought to the table, they would likely find investment opportunities since there would be a lot of synergy between surface transportation modes. Because of the NWS policy not to provide tailored weather services to specific transportation sectors, except aviation, the only way to ensure that the unmet needs for surface transportation road weather information are addressed is for the agencies representing the sectors to take the lead. In the case of road weather, the FHWA should take the lead.

What organizational options should be considered?

Given that weather impacts all modes of transportation, it may be appropriate to include the U.S. DOT Office of Intermodalism. The Office of Intermodalism is responsible for coordinating DOT projects that involve more than one mode of transportation. The road weather initiative would certainly fall into this category since it would add a second weather program within the U.S. DOT (FHWA and FAA). An advisory committee made up of representatives from each mode plus representatives from NOAA (e.g. OFCM, NWS), DOD, NASA, NSF and others (e.g., AASHTO) could participate. At this level, the primary objective of the committee would be information exchange by keeping abreast of individual projects, identifying leveraging opportunities, and sharing information that could benefit other programs. Broad scale weather issues that could impact or benefit all modes could be discussed and coordinated at this level. Broad scale issues would include issues related to the provision of national scale weather services (e.g., radar, satellite, surface observations, data sharing and dissemination), data exchange between transportation modes, decision support system designs, operational concepts, and policy.

Although the Office of Intermodalism could provide a coordination and information exchange role, the responsibility for direct management of weather initiatives for each mode should remain within the individual administrations to ensure that the specific needs of each stakeholder group are addressed.

Another benefit of keeping the direct management of weather initiatives at the administration level is that each administration would have more flexibility in building project teams, identifying budgets, coordinating stakeholder involvement, and disseminating results to various users at conferences, meetings, etc. The project team-building concept is critical because each project may require a different set of skills. Flexibility in the selection of partners and the process used to build project teams is required. For a road weather research program, FHWA project teams may include research organizations (e.g., Volpe National Transportation System Center), the private sector, universities, national laboratories, consultants, etc. The make-up of the teams should be based on the problems being solved and the expertise required to address them.

The FHWA does have a road weather program and it is appropriately titled the Road Weather Management Program (RWMP). The RWMP is located in the Office of Transportation Operations (HOTO). Funding for many of the road weather projects comes from the ITS-Joint Program Office (ITS-JPO).

If a larger and broader road weather research program were established within the FHWA, where should it be placed?

Weather plays a role in emergency management, incident management, maintenance, and traffic management. HOTO provides national leadership for the management and operation of the roadway system and works closely with state DOT end users. As mentioned previously, HOTO is looking forward to a national capacity of advanced capabilities (including weather) that will improve the performance of the transportation system. In addition, RWMP is heavily focused on decision support systems for their stakeholders, which would help keep a road weather research program focused on end user needs. The progressive nature of HOTO makes it an ideal home for a results oriented weather program. However, other offices that deal with construction/infrastructure and the environment/air quality should be involved.

There are certainly weather solutions that are operational in nature or close to being operational that with some tailoring could go a long way in supporting operational decisions. But, highway officials have also expressed a desire for decision support capabilities that are not on the shelf or close to implementation. Capabilities that require very detailed and specific weather and road condition prediction information on small scales will require additional research and development over longer time periods.

Given that the development of road weather projects and capabilities will span the spectrum from research to operations, it may be appropriate to create a road weather research program management structure (a joint program office?) that allows some program elements to be managed by the research side of the organization and others by the operations side. The key to this type of arrangement is to make sure there is a path to operations for the longer-term research efforts.

5 FEDERAL, STATE, AND LOCAL COORDINATION ISSUES

Because the roads are operated by the state and local DOTs, it is imperative that the states be intimately involved in any federally sponsored road weather research program from the beginning. Success will ultimately be determined by whether the states implement these new capabilities. State DOT personnel must be involved in the requirements, design, and testing process. This adds an additional level of complexity to the program because of additional implementations. In many cases, state DOT participation (travel costs) in FHWA-sponsored meetings must be reimbursed for a state DOT to approve travel. This is worth the effort and cost, as it will ensure successful product acceptance by soliciting feedback and getting buy-in for the program.

Another factor that must be considered in the planning of a road weather research program is the role that the states can play in contributing to the program. Because research funds are limited, many states pool their research funds and share the results. A good example of a pooled fund weather program is the Aurora Program. Aurora is an international partnership of public agencies that work together to perform joint research activities in the area of Road Weather Information Systems (RWIS). The advantages of including pooled fund programs in the overall program plan is that they leverage state and federal resources, provide a communication and coordination function, and accelerate the time it takes to get new technologies implemented.

The state DOT personnel and the travelers within the state are the end user customers. One must ensure that any new capabilities, whether they are new weather sensors, products or integrated decision support systems, can be tailored for individual states and the travelers within those areas.

Local jurisdictions should also be given the opportunity to benefit from any capabilities that are created through a road weather research program. Local jurisdictions may include toll authorities, city, or county transportation departments. Although they may not be heavily involved in the development of the systems, their feedback will likely be useful for ensuring a solution that has broad support.

6 PUBLIC-PRIVATE-ACADEMIC COORDINATION ISSUES

Because state DOTs generally purchase their weather information systems from the private sector, it is imperative that the private sector be involved in any federally sponsored road weather research program. In addition, because success will ultimately be determined by whether the states implement the new capabilities, the private sector must be in a position to provide the capabilities in a cost effective manner. That means that every effort should be taken to design solutions that utilize readily available components or data sets.

Private sector participation extends beyond just the tailored weather services providers for states. New technology industries such as intelligent vehicle initiatives by the major automobile manufacturers should be kept in the loop.

Technology transfer is also critical as it will impact the time to market advanced road weather decision support capabilities. Federally funded research programs that result in proprietary technologies do not, in general, create a competitive market and may cost the states more money in the long run. A public, non-exclusive, release of technology provides a more level playing field for the private sector as all stakeholders are being provided an opportunity to participate and take advantage of the results of the program.

What is the appropriate role for the private sector, academia, and national laboratories in a road weather research program?

The private sector plays a pivotal role in providing operational road weather services and should be given the first opportunity to address user needs. However, there are not commercially available solutions for all problems and because of the complex nature of weather and road condition prediction and sensing, the research and development required to address the problems often require a significant level of expertise. The resources required to perform the work are often beyond the scope of the private sector. In these circumstances, it is appropriate to engage academia and national laboratories with the appropriate expertise.

Another factor that must be considered when planning a technology development program is that the end users are often skeptical that a significant leap in capability can be made. It is because of this skepticism and the significant investment needed to develop a solution that the private sector may not aggressively invest significant resources to develop a product line unless it can be shown that a solution is feasible and marketable. This situation presents an obvious “Catch-22” because it cannot be fully determined in advance if the new technology will work in practice. The private sector is usually eager to sell a product if there is a market, but until a capability can be successfully demonstrated, the market remains uncertain. In many cases, the only way to determine the utility of a system is to build a functional prototype. If the feasibility and benefits of a prototype are demonstrated and the technology is made available to the community, open market forces will take over. Because this process can be risky, expensive and requires an open development environment, it may be better suited for the research community.

How should individual road weather projects be organized?

There always seems to be a debate about how individual projects should be organized and staffed to be effective and efficient. Who should take the lead? What organizations should be involved? What is the right mix of people? These are important questions and the answers are not always obvious. There is an ongoing discussion in the weather community about how a road weather research program should be organized. Should it be organized around weather phenomena (winter storms, thunderstorms, surface winds, etc.) or decision categories (winter road maintenance, traffic management, emergency management, etc.)? Should transportation weather research centers be created around the country to perform the work or should the lead organization be chosen, based on the problem at hand?

The FAA aviation weather program is organized around aviation weather hazards (e.g., turbulence, in-flight icing, and thunderstorms) and the participants are primarily the national labs with some university support. Decision support systems and products tailored for pilots, airlines and aviation meteorologists are developed for each of the hazards. Product Development Teams (PDTs) are used to perform the end-to-end (research to solution) work. The PDTs include staff from several organizations and the team makeup is based on expertise. The development process is open and end users and the private sector participate. The PDT lead organization is chosen based on its project management, scientific and engineering expertise, credibility, and performance.

A refined version of the FAA weather research program approach is proposed here. Development teams should be formed around the end user because the expertise, technologies, and user interfaces must be tailored to address specific decisions. For example, the development of a winter road maintenance decision support system requires a different set of technologies than a traffic management decision support system. Rather than PDTs, perhaps Technology Development Teams (TDTs) could be used since the resulting technologies, not fully operational "products," will be made available openly for the private sector and other service providers to operationalize.

The TDT lead organization should be chosen based on their project management, scientific and engineering expertise, subject matter knowledge, credibility, and performance. The makeup of the TDTs should be based on expertise and experience and include staff from organizations with relevant experience. The lead organization could be rotated if necessary or shared. The important factor in the makeup of the TDTs is the ability to be flexible. The program must be structured to add or remove participants as the needs arise and requirements change.

7 CONCLUSION

Weather has a major impact on the national highway system. Thousands of deaths and hundreds of thousand of injuries occur each year on the roadways during poor weather conditions. In addition, the national economy is highly dependent on a safe and efficient transportation system, which is becoming more congested every year. A proactive approach for dealing with weather and the transportation system must be taken to reduce casualties and improve system efficiency before gridlock becomes more widespread.

It is time to get started. New weather and road condition measuring technologies are coming to fruition which, given time and appropriate resources, are likely to produce significant benefits to the surface transportation community. A long term, multifaceted road weather research program utilizing a public-private-academic partnership approach should be established in order to properly address end user needs and to extract the scientific and technical capabilities that reside in organizations (government and private) across the country. A 21st Century solution is required.

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ACRONYM GLOSSARY

AAR	Association of American Railroads
AASHTO	American Association of Highway and Transportation Officials
AWRP	Aviation Weather Research Program
DOD	Department of Defense
DOT	Department of Transportation (Federal)
DSS	Decision Support System
HOTO	Office of Transportation Operations
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMA	Federal Maritime Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
ITSA	Intelligent Transportation Society of America
MARAD	US DOT Maritime Administration
MDSS	Maintenance Decision Support System
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NHSTA	National Highway Traffic Safety Administration
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
OFCM	Office of Federal Coordinator for Meteorology
RSPA	Research and Special Projects Administration
RWIS	Road Weather Information Systems
RWMP	Road Weather Management Program