NCHRP Project No. 20-07/Task 287

GRAND CHALLENGES: A RESEARCH PLAN FOR WINTER MAINTENANCE

Requested by:

American Association of State Highway
and Transportation Officials (AASHTO)

Standing Committee on Highways

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DISCLAIMER

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Introduction

The impacts of winter weather on both safety and mobility are substantial and well known. Accordingly, the need to perform winter maintenance activities on roadways is readily apparent. However, changing social needs, combined with often increasing environmental awareness mean that the methods used to perform winter maintenance are and have been changing. A number of obvious factors, such as climate change, sustainability, environmental stewardship, and changes in how goods are delivered by way of the surface transportation system, are all impacting how winter operations are conducted. These changes are also creating novel constraints on the methods that are available for winter maintenance--the "tools in the toolbox." There is thus a need to identify the grand challenges that face winter highway maintenance operations, and to determine the research needed to address these challenges.

This study was requested by AASHTO (American Association of State Highway and Transportation Officials) and specifically by the Standing Committee on Highways (SCOH) on behalf of Subcommittee on Maintenance. The members of the task group that guided this study are listed in the Acknowledgements. The study took as a starting point the various research that has been conducted in the field of winter maintenance, together with various research needs statements developed by certain pooled fund groups (e.g., Clear Roads, Aurora, and the Peer Exchange meetings). Appendix B includes a bibliography of reports and other technical documents that helped to inform the discussions in the workshop. The objective of the study was to identify the grand challenges which must be met to allow winter maintenance operations to successfully adapt to the changing constraints that these operations face. The order in which the research areas within the grand challenges should be addressed has not been considered in great detail, primarily because such ordering will depend on the availability of research funds going forward. Some research areas must obviously be addressed before others, simply because those other areas build upon the work that will be done.

The method used to develop the grand challenges and their respective components follows that used in similar projects for the AASHTO Highway Subcommittee on Bridges and Structures and the AASHTO Joint Technical Committee on Pavements. A workshop was convened to review the recent research findings and to develop and refine the grand challenges in winter maintenance. The workshop was conducted on August 2-3, 2010 at the National Academies' Arnold and Mabel Beckman Center in Irvine, California. Participants included members from the AASHTO Highway Subcommittee on Maintenance (SCOM), i.e., individuals from state departments of transportation), personnel from public agencies that conduct winter maintenance, the Federal Highway Administration (FHWA), academia, and consultants. A list of participants is provided in Appendix A. The information resulting from the workshop is a set of critical issues in winter maintenance (termed "grand challenges") that would, if solved, lead to significant advances in winter highway maintenance operations. The grand challenges will provide guidance to SCOM and others in identifying, evaluating, and prioritizing research problem suggestions to ensure that the various research efforts being undertaken in the field of winter maintenance are focused in such a way as to provide a quality-based research program that will not only be closely aligned with the needs of the winter maintenance community but will also be as efficient as possible in developing new methods to meet those needs.

Grand Challenges

Through a consensus-building process, workshop participants identified six grand challenges, each of which presents a thrust area for research on a specific aspect of winter highway maintenance. Workshop participants also recognized that while dealing with these challenges will require a major research effort and substantial funding, it will provide opportunities for improvement in winter highway maintenance effectiveness and accruing benefits in terms of enhanced safety, environmental impacts, and economic savings. The six grand challenges, in no specific order, are as follows:

- New Technology for Winter Maintenance
- Balancing Social, Environmental and Economic Factors
- Systems Management for a Consistent and Reliable Network
- Increasing the Recognition of the Value of Winter Maintenance
- Developing Comprehensive Communications Capabilities
- Recruiting, Development, and Retention of Winter Maintenance Work Force

A discussion of each grand challenge is provided in the following sections.

New Technology for Winter Maintenance

Description

Significant improvements in winter highway maintenance can come from the introduction of new technologies (materials, equipment, and methods). However, in many instances successful research is not moved into practice since the transition from research to deployment faces technical, institutional, and other barriers and takes a long time. While there has been some introduction of new technology in recent years (e.g., tow plows, wing plow guidance lasers, extendable plows) the rate of introduction of this new technology seems low in comparison with other areas in transportation. In this regard, it is important to develop a pipeline whereby new ideas can be taken through research and development into various levels of field testing and ultimately deployment. To the extent that such a process or pipeline could be formalized, significant benefits could be gained for the practice of winter maintenance.

Important Activities/Areas of Research

Seven areas of research were identified for this grand challenge, but of these seven, two were areas of which were identified in other grand challenges (closely enough as to not require duplicative elaboration here). These include moving toward effective zero contaminant chemicals materials or methods for snow and ice control and establishing an appropriate method to share information on novel technologies rapidly and effectively.

The five new areas of research are: developing tools to determine the effectiveness of new technologies; creating innovation-friendly cultures in winter maintenance; creating pathways from research to full deployment; criteria for determining best practices in winter maintenance; and, seamless integration of environmental issues into all areas of winter maintenance development.

Developing Tools to Determine the Effectiveness of New Technologies

When new chemicals, materials, equipment, and methods for snow and ice control are conceived and introduced, their benefits must be measured. Although some tools already exist in this regard, other measurements of effectiveness are needed but cannot currently be made. An example would be the need for tools to measure how long, and in what concentration, ice control chemicals remain on the road after application, for a combination of conditions including different weather, and different traffic levels. In addition, it is unclear how laboratory tests and field performance are actually related. While this difficulty is particularly severe in areas such as corrosion, it is a general difficulty. A preliminary part of this area of research will thus focus on the mechanisms that occur after a chemical or material is applied to the road under a variety of weather and traffic conditions.

Creating Innovation-Friendly Cultures in Winter Maintenance

Creating a culture for the winter maintenance community that embraces new technology and is willing to evaluate the technology fairly and thoroughly is essential. A first step in this activity will be to find examples of cultures that exhibit these traits and use those examples as case studies to identify what brings those traits or characteristics into being.

Creating Pathways from Research to Full Deployment

The path from conception to deployment is not easy for even the best idea. There is a clear need to create a series of pathways to take new ideas and technology from research through to full deployment. In winter maintenance, many ideas are developed at the level of individual maintenance yards. Yet these ideas, even though they may be excellent, do not often move beyond their location of origin, to the detriment of winter maintenance practice in general. The workshop identified a need for multiple pathways by which ideas, whether for new equipment, new materials, new methods, or something else, can be thoroughly evaluated and then shared with the broader winter maintenance community. One early task in this regard is the identification of case studies where good new ideas have made this transition. The case studies should identify why some ideas have succeeded while others have not.

Criteria for Determining Best Practices in Winter Maintenance

A common phrase in many areas of transportation today is the “use of best practices.” Clearly, any agency would wish to use the best available practices in their work, but in winter maintenance there are questions as to how that best practice is determined. A particular issue in this regard is that best practices will likely differ for different winter climates, and even for different societal conditions.

Seamless Integration Of Environmental Issues Into All Areas Of Winter Maintenance Development

As noted in the grand challenge dealing with balancing social, economic, and environmental impacts, sustainable winter maintenance needs to be developed. Such development will require that environmental issues must be seamlessly integrated into all technological development for winter maintenance going forward. Recent years have seen increasing concerns over the effects of winter highway maintenance activities on the surrounding environments (air, surface water, underground water, soil, vegetation, etc.), on the transportation infrastructure (e.g., pavements and bridges), and on the motor vehicles (in terms of corrosion). It would be extraordinarily beneficial if certain practices,

either currently in use, or to be developed in the future, could be somehow certified or identified by appropriate state environmental agencies (and possibly even by the EPA) as environmentally appropriate practice. This might include the formation of special advisory groups or panels to examine such practices, which groups could include representative of environmental agencies and perhaps even of environmental interest groups. However, regardless of the method used (the determining of the optimal method to be used is part of the needed research) environmental concerns can no longer be an afterthought in winter maintenance, but must instead be considered one of the primary governing factors in winter service activities.

Anticipated Outcomes and Benchmarks

Success in this grand challenge will bring about numerous instances of new technologies in winter maintenance, together with efficient methods of bringing that new technology into full practice across the United States. The following benchmarks will indicate progress on this challenge:

- New tools to measure the performance of ice control chemicals and other methods and equipment will be developed and implemented
- The relationships between laboratory testing and field performance will be explored and understood
- The mechanisms that occur after a chemical is placed on the road under a variety of conditions will be described
- Case studies of work cultures that embrace and evaluate new technologies will be made and the traits common to such work cultures will be elucidated
- Pathways allowing the effective movement of new ideas from concept to deployment will be identified and by way of case studies and other means shared with and adopted by the winter maintenance community
- Guidelines to identify what constitutes best practices in winter maintenance will be developed and used
- Environmental concerns will be fully integrated into all levels of winter service activities

Importance and Readiness

Without new technologies, any area within transportation will become less effective over time because the demands on the transportation system are growing over time and the constraints on possible actions to meet those demands are becoming more constricting. Therefore, if winter maintenance is to continue to be effective, a steady stream of innovations in materials, equipment, and methods is needed. At present, that stream is only a trickle, and it needs to grow. Difficulties in achieving this grand challenge are primarily institutional or cultural. Changes in technology are currently often hampered by institutional factors, and thus the institutional and cultural factors and behavior must change.

At its most fundamental, this grand challenge represents the inevitable differences between the various DOTs. This challenge reflects the fact that some system of harnessing the financial and administrative power of these independent agencies for the common good must be found.

Balancing Social, Environmental and Economic Factors

Description

If winter maintenance practices are to be sustainable, then deliberate consideration must be given by each winter maintenance agency as to how the social, environmental, and economic "costs" of providing that winter maintenance should be balanced. In considering this, it must be noted that the balance of these three factors will vary from location to location - for example, in some, more arid, areas, the use of chemicals will be perhaps of greater concern that in other areas with high annual rainfall. Further in a given location, the balance may shift over time, as populations shift and as available funding changes. Therefore, any solutions to this "balancing act" must be dynamic - that is, they must change over time as circumstances change - and must be resilient - that is they must be attainable even if funding is significantly reduced or other substantial, "upsetting," changes occur, even if that means the attainment may be more limited. While developing the tools, equipment, methods, and materials to attain this balance is complex, this is quite simply an area that must be addressed at this time.

Important Activities/Areas of Research

Five areas of research were identified for this grand challenge: environmentally friendly, economic chemical alternatives; a holistic approach to sustainable winter service; managing the impacts of winter maintenance on society, the economy, and the environment; preparing for the impacts of climate change on winter maintenance practices; and developing mechanisms for networking with others with environmental concerns.

Environmentally Friendly, Economic Chemical Alternatives

This area addresses the concern that the materials currently used in winter maintenance carry some degree of environmental burden. The goal is to find new materials, methods, equipment, or other technologies that reduce the current environmental burdens. This goal is balanced by the fact that winter maintenance brings about environmental good. To the extent that improving safety reduces crashes, and improving mobility decreases travel congestions and delay, winter maintenance is clearly an environmental positive. Every crash is a localized environmental disaster, and every traffic congestion event results in needless vehicular emissions. Nonetheless, there is a clear need to minimize the environmental burden that currently arises from winter maintenance actions, to improve the sustainability of winter maintenance practices.

A Holistic Approach To Sustainable Winter Service

The issue in this regard is that too often winter maintenance is seen as a collection of disparate parts - individual routes, individual trucks, and so forth. In fact, of course, all the routes are connected and all the trucks work in concert to some degree. But if methods could be developed which focused on operating the various winter maintenance tools holistically, the efficiency of winter maintenance practices could be substantially enhanced. This area of study begins with examining levels of service with the intent of balancing safety and reliability with environmental concerns. The use of materials management best practices and the development of more robust decisions support tools will allow this balance to be achieved with optimal use of resources, and by including issues of access and mode choice this will allow livability to be enhanced also.

Managing the Impacts of Winter Maintenance on Society, Economy, and the Environment

To some degree this area is a subset of the first two areas identified, but neither of those independently covers this area completely. The goal in this area would be to quantify the negative impacts of ice-control materials on air, water, soil, infrastructure, and vehicles, and to explore means of mitigation that incorporate materials transport (e.g., Total Maximum Daily Load) and corrosion. This can be thought of as developing a series of "maps" that show the pathways that the materials placed upon the road during winter maintenance take after their placement, and what their end impact will be. By identifying the pathways it may be possible to adjust certain practices so that more fragile pathways are protected in favor of pathways that are less susceptible to environmental damage.

Preparing For The Impacts Of Climate Change On Winter Maintenance Practices

At present it is not possible to predict with sufficient degree of certainty what changes a given location may see in winter climate over the coming decades but this does not absolve agencies of the need to be prepared for changes. To that end there is a need for developing flexible plans to adapt to the impacts of climate change upon the transportation system with particular emphasis on winter maintenance impacts. For example, if a given area that currently sees snow in winter were to experience warmer winters, the area may experience more freezing rain and less snow than previously. Methods are needed to allow agencies to examine how their practices in winter maintenance would need to change for a variety of possible climate change scenarios, and how they could make such changes in such a manner as to maximize efficiency and minimize costs.

Developing Mechanisms For Networking With Others With Environmental Concerns

The winter maintenance arena of practice needs guidance on how best to create partnerships with environmental groups, groups concerned with reliability for freight transport, and other similar groups so as to bring the optimal effort to bear on the issue of sustainability in winter maintenance. This can best be achieved through the documentation of some case studies that highlight best practices.

Anticipated Outcomes and Benchmarks

The anticipated outcome of successful completion of the research needs for this grand challenge would be the broad adoption of sustainable practices in winter maintenance. These practices would lead to a reduction in environmental impact of winter maintenance activities together with new methods, materials, equipment and techniques that allow these reduced impacts to be achieved. Additionally, agencies would take a more systems or holistic approach to winter maintenance activities in general. The following benchmarks will indicate progress on this challenge:

- Use of materials, methods, and equipment or other technologies that reduce adverse impact on the environment, infrastructure and vehicles by agencies
- Development of methods that allow for the robust measurement of environmental costs and benefits in winter maintenance
- Widespread acceptance of maintenance decision support systems (MDSS)
- Determination of the total maximum daily loadings (TMDLs) that cause acceptable local and regional environmental impacts for various contaminants that may arise from winter maintenance actions

- Determination of the sources of the various contaminants that may arise from winter maintenance actions
- Conduct of robust measurements of the environmental benefits of winter maintenance actions and their acceptance for use in the development of sustainable winter maintenance actions
- Development of guidelines for methods to achieve optimal environmental protection consistent with desirable levels of winter maintenance service
- Gathering of case studies that demonstrate how agencies have managed climate change issues in winter maintenance
- Deployment of versatile adaptation plans for managing impacts of climate change on winter maintenance needs
- Formalization of processes that enable and enhance the ability of winter maintenance agencies to work with other environmentally concerned groups, agencies, and industries.

Importance and Readiness

It is critically important that winter maintenance practices become well grounded in a sustainable process. To that end, the various needs identified in this grand challenge have to be addressed. Many of these needs may require significant and fundamental breakthroughs. For example, the development of an affordable ice-control chemical that has no adverse environmental effect may seem unlikely, yet it is a goal that would be enormously valuable if achieved. Impacts of climate change on transportation are still being evaluated, as is the whole concept of sustainability and livability in transportation, and it may be that winter maintenance may serve as a useful case study in the developments outlined as necessary in this challenge. Much of the change identified in this grand challenge is a change in the way of thinking for agencies, rather than necessarily a change in equipment or methods (although changes in equipment and methods may result once thinking has changed). As such, the technical barriers are not necessarily large, but those barriers that do exist will not be trivial either.

Systems Management for a Consistent and Reliable Network

Description

Road users are often unaware of boundaries between agencies or between districts within agencies across which the methods of winter maintenance may differ significantly. This means that sometimes road users may face substantial changes in the condition of the road surface at locations that do not appear to be special in any particular way. Unbeknownst to the road users, the location may mark where one regime of winter maintenance ends and another begins. It is possible for road users to go from bare and wet roads to roads covered in snow-pack in a few feet. This is not an acceptable occurrence. The problem herein is that too often agencies, for a variety of reasons, do not consider that the road system within their area of responsibility is only part of a much larger road system. From the point of view of the road user, even important political boundaries such as state lines seem unimportant when driving cross country, for example. The reliability and safety of the road network requires that the network be seen as an interconnected system rather than a series of discrete bundles that happen to abut one another at certain points.

Important Activities/Areas of Research

Two areas of research were identified for this grand challenge: providing the road user with consistency and reliability along corridors and regional networks; and establishing consistent national level of service and performance measures for winter maintenance.

Providing Consistent and Reliable Road Condition along Corridors and Regional Networks

This will require that agencies establish intra and inter-jurisdictional consistency and reliability along corridors and regional networks. This in turn will allow for enhancing inter-jurisdiction coordination and resource sharing (e.g., synchronization of plow trains). There are a few examples of such corridor approaches both within the US (The I-80 coalition) and elsewhere in the world (e.g., the E-18 highway in Scandinavia) and these examples may be useful as case studies from which more general guidelines and protocols can be derived.

Establishing Consistent National Level of Service and Performance Measures for Winter Maintenance

This is a very challenging task and will face a number of difficulties, some of which will arise from the attempt to balance social, economic, and environmental impacts. The idea of sustainability implies that local jurisdictions need to consider the local intersection of economic, environmental, and societal needs, and thus it is to be expected that there will be differences in levels of service for different communities around the United States. It might seem that striving to identify national LOS and performance measures is inconsistent with the need for a sustainable approach but this need not be the case. In some circumstances, national needs and concerns may need to have priority over local needs and concerns. Part of the needed research in this area is to determine the proper relationships between national and local needs, and identifying methods for determining which needs should have priority. Additionally, research should address issues such as network prioritization, contract resources, and a consistent winter severity index (by storm and by season).

One particular difficulty with the issue of a National LOS is that road terrain is very variable across the Country. At present, to take I-80 as an example, we have major highways that go from relatively flat terrain (in Nebraska and Iowa) through terrain that is sufficiently mountainous that chains are required in winter weather (for example, over the Donner Pass in California). Thus any move toward a National LOS must be tempered by consideration of the responsibilities of the road users on the Highway System.

Anticipated Outcomes and Benchmarks

The ultimate measure of success in this grand challenge is that road users should not encounter unexpected changes in levels of service at locations where nothing indicates such a change might occur. Actions for achieving this goal would be the establishment of various corridor coalitions and similar agreements between agencies that adopt a network oriented approach to winter maintenance rather than a road segment by road segment approach. The following benchmarks will indicate progress on this challenge:

- Establishment of model processes (e.g. model memoranda of understanding) to accomplish suitable agreements between agencies for corridor and network wide approaches
- Collection of case studies on corridors that are showing exemplary success in this regard

- Establishment of consistent levels of service and performance measures
- Evaluation and investigation of typical institutional issues that make such cooperative agreements difficult to create and maintain
- Demonstrations of the value of using clearly defined and consistent levels of service in winter maintenance
- Study of the upcoming NCHRP report on Interstate Levels of Service, and quantification of how it applies to winter maintenance
- Quantification of the expectations of road users for consistent levels of service.

Importance and Readiness

From the point of view of providing a reliable and robust road network, this grand challenge is critically important. Network wide reliability and safety cannot be achieved unless and until a network wide approach to reliability and safety is taken. As noted in the above discussion some studies are already underway on this issue, and these should be used as a foundation for the additional research that is needed. The most difficult aspect of this challenge may be in the implementation of the research results, as this will require overcoming inter-jurisdictional issues that may have existed for many years.

Increasing the Recognition of the Value of Winter Maintenance

Description

The winter maintenance community would benefit significantly if its story could be clearly articulated and widely disseminated. This would allow the public, transportation administrations and governmental bodies to clearly understand the impact of winter maintenance on safety, mobility, the environment, and economic benefits and thus insure that adequate funding will be consistently available to provide suitable levels of service.

Important Activities/Areas of Research

Five areas of research were identified for this grand challenge: developing comprehensive tools to demonstrate the cost/benefit effectiveness of winter operations; methods to capture all winter maintenance costs and benefits; collecting and identifying the critical economic data for winter maintenance; the use of contract work forces for winter maintenance; and marketing tools for winter maintenance.

Developing Comprehensive Tools to Demonstrate The Cost/Benefit Effectiveness of Winter Operations

While a number of studies have been conducted in this area, there is concern that these studies have not been able to capture a complete picture of the costs and benefits, perhaps because they have conducted, for the most part, by winter maintenance experts. By creating links with experts from other fields (e.g., economics and business) it is possible that a more complete picture can be created and thus attain greater legitimacy in areas outside of winter maintenance.

Methods to Capture All Winter Maintenance Costs and Benefits

Methods do not yet exist that allow a winter maintenance agency to measure and compare the costs and benefits of given winter maintenance actions with sufficient breadth to include non-obvious (to the

winter maintainer) factors in the analysis. These methods should be simple to use and the data to drive them should be readily accessible and measurable.

Collecting and Identifying the Critical Economic Data for Winter Maintenance

While intuition provides some guidance as to which data are critical in this regard the need remains to comprehensively identify which data are needed for the measurement of costs and benefits of winter maintenance and to develop the tools to collect the critical data in a cost-effective manner. Clearly this is a complementary the area of collecting critical economic data, but it is distinct. Its importance lies in the fact that if the wrong information is used in any cost-benefit model, meaningless data will be generated by the model. Further, knowing which data are important will allow agencies to concentrate on improving those data, thereby improving their cost-benefit ratios and their efficiency.

The Use of Contract Work Forces for Winter Maintenance

Accurate, reliable and effective tools are needed to compare the effectiveness and efficiency of using in-house versus contract work forces for winter maintenance. These tools should allow for direct comparison between these options, and should be transparent so that the decision making with regard to which approach is taken is readily apparent.

Marketing Tools for Winter Maintenance

Decision makers need to know the benefits of winter maintenance, and need to understand the value of investing in this area. Present efforts in this regard have not been fully successful, suggesting a need for new tools to convey the message. This will need to include in particular non-verbal methods of communications largely because they are likely to be more effective than the more traditional approach (of reports and briefings). Such non-verbal methods would include visually oriented presentations, using both video and still shots, and including graphs and charts that have been designed to inform and elucidate information as effectively as possible.

Anticipated Outcomes and Benchmarks

Any maintenance activity such as winter maintenance requires funding, and if capabilities for winter maintenance are to improve, the arguments for that funding need to made with great effectiveness. If the areas of need in this grand challenge are met, then the resources to allow improved winter maintenance operations will be made available. The following benchmarks have been identified:

- Improved recognition of the value and benefits of winter maintenance
- Improved ability to maintain a stable level of funding
- Enhanced measures of the effectiveness and efficiency of various winter maintenance practices
- More complete understanding of which data are needed to fully measure costs and benefits of winter maintenance operations

Importance and Readiness

Obtaining funding is critical to the ability to move winter maintenance practices forward. Funding depends on the ability to convince those with funding authority that a given set of tasks provides benefits greater than their costs. Given this reality, this grand challenge is of particular importance for the winter maintenance community. Success in this challenge will depend on the willingness and ability

of the winter maintenance community to work with experts in other fields to refine the management tools currently in place and thus to improve efficiency.

Developing Comprehensive Communications Capabilities

Description

Good winter maintenance practice requires good decision making, and good decision making requires good information. Information is, in many ways, the lifeblood of winter maintenance. Ensuring that the right information gets to the right place at the right time is critical and this requires a suite of communications capabilities.

These capabilities must be able to deliver information to a range of end users. Obviously, one important set of end users are those who conduct winter maintenance operations. Other end users include travelers, emergency and incident responders (e.g. police, fire, EMS, towing), traffic management facilities, and the media. The methods of communications are wide ranging and are increasing significantly. For the most part, current communication systems require action on the part of the end user of the information being communicated. This includes traditional media (radio, TV) and the emerging media (Internet, satellite radio). However, there are an increasing number of communication modes that can be considered "push" technology - that is, they will deliver information to the user directly without the user having to ask for it on every occasion that it is needed. Thus, an end user might subscribe to a twitter account that provides winter weather information, and every time an event of significance occurs, the end user will receive a tweet.

These more invasive forms of communication provide the opportunity for getting critical information to target users rapidly, but they also are easily misused to the point of becoming of no value. Care will be needed to ensure that the newer "push" technologies (as well as more traditional forms of communication) are effective and efficient at communicating critical information to key end user communities.

Important Activities/Areas of Research

Five particular areas of research were identified for this grand challenge: the identification and transfer of information; leveraging communications technology to enable maintenance professionals; enhancing integration between maintenance and operations activities; promoting resource sharing for more efficient operations; and warehousing winter maintenance efforts across numerous groups and agencies.

Identification and Transfer of Information

The end users of information must be identified and the specific information of interest to each end user must be clearly defined. In each case, the optimal methods of delivery must be developed. The challenge in this area is that much of the information that is needed must be collected from different sources (e.g., from snow plow operators, from value-added meteorological service providers, etc.), integrated into appropriate forms and then delivered. Thus there is need for significant trans-jurisdictional issues to be addressed, as well as concerns over compatibility between different systems of data collection and integration. Additionally, while much of the needed data are currently easily

obtained (e.g. road surface temperature) means of collecting other critical data (e.g. road surface condition) are not yet fully determined. In terms of methods of delivery, the issues are not merely what technology should be used, but also how best to display the messages so as not to distract but rather to inform. Thus this will require collaboration in the areas of communications technology and human factors as a minimum.

Leveraging Communications Technology to Enable Maintenance Professionals

The focus in this area is on ensuring suitable specifications and open access protocols such that communication is not hampered by proprietary systems. The development of standards that encourage or require open architecture in communication systems is a critical part of this effort, and the benefits of such open systems will be significant. This is of particular importance because the volumes of data being generated now and likely to be generated in the future will require smart database systems that allow real-time mining of the data in a wide variety of ways.

Enhancing Integration Between Maintenance and Operations Activities

In this context, operations is seen to include dispatching services, freeway operations, variable message signs, traffic management and traveler information as examples. Maintenance includes actions directly associated with clearing snow and ice from the roads. Workshop members saw a clear and urgent need to link maintenance activities with operations and incident management activities through integrated communications and data management systems. Particular challenges in this regard include identifying ways in which all activities can be optimized and streamlined by the linkages being sought.

Promoting Resource Sharing for More Efficient Operations

There are a broad range of ways in which such resource sharing can be achieved. These include such methods as memoranda of understanding, and other road sharing agreements. Model forms for such agreements should be developed, and possible pitfalls in the development and use of such agreements should be identified, together with methods to pre-empt or avoid such pitfalls. In such areas, existing success stories can be very useful to encourage further agreements, so collection of such information should be undertaken.

Warehousing Winter Maintenance Efforts across Numerous Groups and Agencies

The goal of this area is to insure that investments in winter maintenance research (especially pooled fund studies) are coordinated and shared, and thus not duplicated. While a number of systems already exist toward this end (e.g. the TRB Research in Progress database) for various reasons they are not always used when research projects are being developed. There is an additional concern related to the tendency of the results of research to be reports that sit on shelves, rather than new actions, methods, materials, equipment, or approaches. Possible approaches to this aspect of the problem include creation of some sort of coordinating group or the use of second generation Web tools (such as wikis) to allow for complete and effective sharing of winter maintenance research.

Anticipated Outcomes and Benchmarks

The anticipated outcome of all the research in this regard would be significant improvements in communications on a variety of levels. This would, in turn, lead to an increased capability for making good decisions because of a higher quality of information being delivered to decision makers in a timely

manner. Further, improved cooperation and coordination between a variety of agencies will provide higher levels of service from winter maintenance activities, thus resulting in safer, more reliable highways and roads during winter weather conditions. The following benchmarks will indicate progress on this challenge:

- All professionals and road users are able to make correct decisions because of improved real time strategic and situational awareness
- "Maps" of communication pathways are developed through case studies, thus providing guidance for implementation of improved communication systems
- Effective and efficient responses to emergency are routine, even under the most severe winter conditions
- Definitions of what effective and efficient responses are developed, thus providing clear performance measures in this regard
- Standard national specifications for equipment and interfaces are developed including standards for open access and open architecture
- The quantity and quality of data that are made available both increase and improve
- Model inter-agency agreements give rise to an increase in the number of such agreements, and result in enhanced management of liability for agencies
- Tools allowing for the efficient sharing of planned and completed research are implemented and widely used in the community.

Importance and Readiness

Because decision making depends on information, the communication of that information to decision makers is very important. Improvements in this communication can lead very rapidly to improvements in performance and thus enhance safety and reliability on the highways. For the most part, the technology needed to allow these improvements to occur already exists, although in some areas (e.g., human factors) additional work will be required to optimize the technology. The primary barriers to implementation are human ones. There may be concerns about changing the flows of information or about developing the standards needed for open transfer of information across multiple systems. Nonetheless, much progress in this area can be easily achieved.

Recruiting, Development, and Retention of Winter Maintenance Work Force

Description

The purpose of this grand challenge is to develop outcome-based training methods that will measure knowledge retention among the winter maintenance work force. A major issue defined by both the 2007 and 2009 peer-exchange groups was the issue of work force development. A recently finished project with NCHRP (NCHRP Report 636 "Tools to aid state DOTs in responding to workforce challenges") may provide many solutions in this area. Scenarios within this report need to be populated with winter maintenance workforce information, and this information needs to be disseminated around the winter maintenance community. Additionally, the information contained within NCHRP Synthesis 323 ("Recruiting and Retaining Individuals in State Transportation Agencies") needs to be disseminated and implemented within the winter maintenance community.

Important Activities/Areas of Research

Six areas of need were identified for this grand challenge: efficient training and measuring training effectiveness; tools for winter workforce recruiting and retention; populating scenarios in NCHRP Report 636; certifying winter maintenance personnel; temporary, seasonal, and contract employees; and comprehensive initial training for snow plow operators.

Efficient Training and Measuring Training Effectiveness

This area will include a focus on lower cost, more efficient snow and ice operation including safer operations, consistent operations within an agency, and improved utilization of equipment. To achieve this goal, it is likely that there will be a need for more funding for training. It will also be necessary to explore developing a training system based on various levels of achievement for winter maintenance workers – for example, apprentice, journeyman, tradesman, and master.

Tools for Winter Workforce Recruiting And Retention

Given the way the workforce has changed over the past two decades, agencies need effective tools and guidelines that assist them in recruiting and retaining a diverse work force (i.e. a workforce that represents the population). Many studies have been conducted on this issue in other areas, so this need will likely be most easily met by taking tools and guidelines from other areas and adapting them specifically for the winter maintenance workforce.

Populating Scenarios in NCHRP Report 636

NCHRP Report 636 provides much general information on personnel management, and the scenarios within the report need to be populated with winter maintenance information. This will provide improved personnel management tools for winter maintenance employees and thus help to improve recruiting and retention in the winter maintenance workforce.

Certifying Winter Maintenance Personnel

There are a number of issues surrounding the possible certification of winter maintenance personnel (both public and private, and full-time and part-time employees) that need to be investigated. A parallel can be seen here with the need for employees who spray weeds to be trained and certified. This issue will require establishing criteria for different levels of certification and addressing issues of continuing education once certified.

Temporary, Seasonal, and Contract Employees

Many agencies use temporary, seasonal, and contract winter maintenance employees and determining the optimal mix of work force/staffing resources for given agency conditions is a non-trivial issue. The first step towards meeting this need can most likely be achieved by conducting a synthesis into current practice around the US on this issue.

Comprehensive Initial Training for Snow Plow Operators

Obviously, safety and efficiency of winter maintenance operations will be greatly enhanced if a more coherent and comprehensive approach to initial snow plow training could be taken.

Anticipated Outcomes and Benchmarks

Training is critical both to operator safety and to achieving the best possible efficiency and effectiveness in winter maintenance operations. When this grand challenge has been met, agencies will have a

certified and well motivated work force able to adapt to new technology and rapidly changing conditions, making best use of limited winter maintenance resources. The following benchmarks have been identified:

- Comprehensive methods will be developed to measure the effectiveness of training and thus to customize future training to meet the specific needs of a given workforce
- Tools and guidelines specific to winter maintenance will be developed and deployed that deal with employee recruiting, retention and management. In turn, these tools will enhance agency productivity by way of a more satisfied and fulfilled work force
- The possible certification of winter maintenance employees will be fully examined, and model certification programs will be developed and tested
- The optimal mix of temporary, seasonal, contract, and full time employees will be examined and tools will be available that allow agencies to determine this optimal mix for their own unique conditions
- Comprehensive initial snow plow training will be developed and deployed for new snow plow operators

Importance and Readiness

Ensuring a well trained, well motivated work force will result in a more efficient and effective work force, as well as a work force that will be safer in sometimes very hazardous situations. The work force in the United States is changing, and without the investment in the winter maintenance work force that this grand challenge implies, it will likely become increasingly difficult to recruit and retain the sort of quality work force that winter maintenance requires.

Concluding Remarks

Through a one and one-half day workshop, about twenty winter maintenance professionals from state highway agencies, the FHWA and AASHTO, academia, local agencies, and consulting firms identified six grand challenges that represent thrust areas for research on a specific aspect of winter maintenance operations. If these challenges are met, substantial improvements in winter maintenance operations will result, with concomitant benefits in safety, mobility and environmental impacts. These in turn will bring about significant economic benefits. However, to meet the challenges, significant resources will have to be committed over a lengthy time period (up to ten years or longer). Some of these resources may already exist through coalitions and pooled funds in the general area of winter maintenance, but existing resources cannot address all the challenges identified herein. Therefore, it is necessary to explore new sources of funding and encourage opportunities for collaboration by way of pooled funding.

Appendix A: Workshop Participants

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Appendix B: Bibliography

Akin, M., and Shi, X. "Development of Standardized Test Procedures for Evaluating Deicing Chemicals." Final report prepared for the Wisconsin Department of Transportation and the Clear Roads Program. September 2009. Accessed on December 21, 2010 at http://clearroads.org/research-projects/downloads/08-32deicinglabtest-final-report-rev.pdf.

Al-Qadi, I. L., A. Loulizi, G. W. Flintsch, D. S. Roosevelt, R. Decker, J. C. Wambold, and W. A. Nixon, 2002."Feasibility of Using Friction Indicators to Improve Winter Maintenance Operations and Mobility," NCHRP Web-Only Document 53, accessed on November 6, 2010 at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w53.pdf.

Blackburn, R.R., K. M. Bauer, D.E. Amsler, S. E. Boselly, A. D. McElroy, 2004. "Snow and Ice Control: Guidelines for Materials and Methods," NCHRP Report 526, published by the Transportation Research Board, accessed on November 7, 2010 at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_526.pdf.

Blackburn, R. R., E. J. Fleege, and D. E> Amsler, 2008. "Calibration Accuracy of Manual and Ground-Speed-Controlled Salters," Report No. CR2005-02/0092-06-21 to the Clear Roads Pooled Fund, accessed on November 6, 2010 at http://www.clearroads.org/files/06-21CalibrationFinalReport.pdf.

Burkheimer, D., T. Jackson, G. Thompson, and T. Thompson, 2010. "Development of Interface Specifications for Mobile Data Platforms on DOT Vehicles: Final Report," Report No. CR08-02 to the Clear Roads Pooled Fund, accessed on November 6, 2010 at http://www.clearroads.org/research-projects/downloads/09-09mobiledataplatforms-final-report.pdf.

Fay, L., M. Akin, S. Wang, X. Shi, and D. Williams, 2010. "Correlating Lab Testing and Field Performance for Deicing and Anti-icing Chemicals (Phase 1)," Report to the Clear Roads Pooled Fund, accessed on November 7, 2010 at http://www.clearroads.org/research-projects/downloads/Final%20-%20Correlating%20Lab%20Testing%20and%20Field%20Performance%20for%20Deicing%20and%20Anti-Icing%20Chemicals.pdf.

Fleege, E. J., B. Scott, E. Minge, M. Gallagher, J. Sable, S. Petersen, C. Kruse, C. Han, D. Larson, and E. O. Lukanen, 2006. "Test Methods for Evaluating Field Performance of RWIS Sensors," NCHRP Web-Only Document 87, accessed on November 6, 2010 at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w87.pdf.

Ketcham, S. A., L. D. Minsk, R. R. Blackburn and E. J. Fleege, 1996. "Manual of Practice for an Effective Anti-Icing Program," Report No. FHWA-RD-95-202 accessed on November 7, 2010 at http://www.fhwa.dot.gov/reports/mopeap/mop0296a.htm.

Kruse, C. G., and L. A. Kirchner, 2010. "Development of Standardized Test Procedures for Carbide Insert Snowplow Blade Wear," Report No. CR2007-01 WisDOT 0092-08031 to the Clear Roads Pooled Fund,

accessed on November 6, 2010 at http://www.clearroads.org/research-projects/downloads/Carbide%20Insert%20Blade%20Final%20Report.pdf.

Levelton Consultants Limited, 2007. "Guidelines for the Selection of Snow and Ice Control Materials to Mitigate Environmental Impacts," NCHRP Report 577, published by the Transportation Research Board, accessed on November 7, 2010 at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_577.pdf.

Maze, T.H., C. Albrecht, D. Kroeger, and J. Wiegand, 2007. "Performance Measures for Snow and Ice Control Operations," NCHRP Web-Only Document 136, accessed on November 6, 2010 at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w136.pdf.

Nixon, W. A. "Using a Maintenance Decision Support System in Winter Service Operations," Journal of Public Works and Infrastructure, Vol. 2, No. 1, pp. 74-84, 2009

Nixon, W. A. and L. Qiu, "Developing a Storm Severity Index," Transportation Research Record, Journal of the Transportation Research Board, no. 1911, pp. 143 -148, 2005.

Nixon, W.A., Kochumman, G., Qiu, L., Qiu, J, and Xiong, J., "Evaluation of Using Non-Corrosive Deicing Materials and Corrosion Reducing Treatments for Deicing Salts: Final Report of Project TR 471," IIHR Technical Report No. 463, May 2007.

Proceedings of the PIARC International Seminar on Technical Solution for Sustainable Winter Service, 2009. Held in Hradec Králové, Czech Republic, accessed on November 7, 2010 at http://publications.piarc.org/en/seminars/seminars_09/hradeckralove_October09.htm.

Proceedings of the 15th SIRWEC (Standing International Road Weather Congress) Conference 2010. Held in Quebec City, Canada, accessed on November 7, 2010 at http://www.sirwec.org/conferences/Quebec/sirwec_2010.html.

Purtois, C. et al., 2008. "New Developments for Winter Service on European Roads, European Cooperation in Science and Technology (COST) Publication, accessed on November 7, 2010 at http://www.cost.esf.org/library/publications/08-25-New-Developments-for-Winter-Service-on-European-Roads.

Qiu, L. and W.A. Nixon, "Effects of Adverse Weather on Traffic Crashes: Systematic Review and Meta-Analysis," Transportation Research Record, Journal of the Transportation Research Board, no. 2055, pp. 139 - 146, 2008.

Qiu, L. and Nixon, W. A., "Performance Measurement for Highway Winter Maintenance Operations: Final Report of Project TR 491," IIHR Technical Report No. 474, June 2009.

Shi, X. "Winter Road Maintenance: Best Practices, Emerging Challenges, and Research Needs." Journal of Public Works & Infrastructure 2010, 2(4), 318-326.Thomas, A., K. Linsenmayer, and P. Casey, 2006. "Synthesis of Best Practices for Eliminating Fogging and Icing on Winter Maintenance Vehicles," Report No. CR2005-01 to the Clear Roads Pooled Fund, accessed on November 6, 2010 at http://clearroads.org/FINAL%20Anti-fogging%20Report.pdf.

Transportation Research Board, 2010. “Research Needs Statement for Climate Change and Transportation,” Special Task Force on Climate Change and Energy, Transportation Research Circular No. E-C144, accessed on November 6, 2010 at http://onlinepubs.trb.org/onlinepubs/circulars/ec144.pdf.

Ye, Z., Strong, C.K., Shi, X., Conger, S., and Huft, D. “Benefit-Cost Analysis of Maintenance Decision Support System.” Transportation Research Record 2009, 2107, 95-103.

Ye, Z., Shi, X., Strong, C.K., and Greenfield, T. H. “Evaluation of the Effects of Weather Information on Winter Maintenance Costs.” Transportation Research Record 2009, 2107, 104-110.