RITA Intelligent Transportation Systems Joint Program Office

Road Weather Management Performance Measures – 2012 Update

www.its.dot.gov/index.htm

Final Report — August 6, 2013
FHWA-JPO-13-87

U.S. Department of Transportation
Research and Innovative Technology Administration

Source for Cover Page pictures:

Cover page pictures provided by FHWA (Roemer Alfelor)

Produced by Federal Highway Administration Road Weather Management Program for

ITS Joint Program Office
Research and Innovative Technology Administration
U.S. Department of Transportation

Notice

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-JPO-13-87		

4. Title and Subtitle
Road Weather Management Performance Measures – 2012 Update

5. Report Date
August 6, 2013

6. Performing Organization Code

7. Author(s)
Deepak Gopalakrishna, Chris Cluett, Rachel Klein, Kaniz Khaleda

8. Performing Organization Report No.

9. Performing Organization Name and Address
Battelle
505 King Avenue
Columbus, Ohio 43201

10. Work Unit No. (TRAIS)

11. Contract or Grant No.
DTFH61-06-D-00007;
Task BA07-011

12. Sponsoring Agency Name and Address
United States Department of Transportation
Research and Innovative Technology Administration
Federal Highway Administration, Office of Operations
1200 New Jersey Ave., SE
Washington, DC 20590

13. Type of Report and Period Covered
Final Report
April 23, 2012 –
September 30, 2013

14. Sponsoring Agency Code
HOTO

15. Supplementary Notes
Roemer Alfelor (GTM), Barry Zimmer (COTR)

16. Abstract
In 2007, the Road Weather Management Program (RWMP) conducted a study with stakeholders from the transportation and meteorological communities to define eleven performance measures that would enable the Federal Highway Administration (FHWA) to determine the extent to which its goals were being met. In 2010, FHWA led a task to quantify these performance measures. This report documents a follow-on task to update these performance measures using information which became available since 2012. The focus of this update includes: (1) reviewing existing measures for their continued suitability, strengths, and weaknesses for assessing performance, (2) determining changes to the baseline conditions for existing measures using updated and new data sources, (3) incorporating new performance measures around reliability, the operations efficiency index (OEI), Moving Ahead for Progress in the 21st Century Act (MAP-21), and Safe, Accountable, Flexible, Efficient, Transportation Equity Act – A Legacy for Users (SAFETEA-LU's) Section 1201 rule, (4) identifying refinements necessary to the existing performance measurement framework and developing a plan to quantify the measures; and (5) quantifying all existing and new performance measures using current data to create a 2012 RWMP performance assessment report. The following document includes a discussion on the background for the development and update of RWMP performance measures, the evolution of the measures since 2007 including the approach and data sources used, a description of each RWMP objective and the quantification of each associated measure, and an overall assessment of the RMWP based on the performance measures tracked.

17. Key Words
Road Weather Management Performance Measures, Performance Evaluation

18. Distribution Statement
No restrictions. This document is available to the public.

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	125	N/A

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

This page intentionally left blank.

Acknowledgements

Measuring performance of a Federal program involves the cooperation and participation of a variety of stakeholders. Roemer Alfelor and Paul Pisano provided valuable guidance and leadership to update the performance measures from their original formulation and quantification in 2007-2010. Implementation of the performance measures greatly benefited from the contributions and data provided by the various State DOT personnel and the FHWA Road Weather Management Program (RWMP) staff.

This page intentionally left blank.

Table of Contents

List of Appendices

List of Tables

List of Figures

Executive Summary

Periodic assessments of the performance of transportation program activities and accomplishments have been a priority of the U.S. Department of Transportation (USDOT) as an essential tool for documenting goal attainment and providing guidance as programs evolve. The Road Weather Management Program (RWMP) established a set of performance measures beginning in 2006 and began collecting data in order to assess progress toward meeting each of their major program goals under the Safe, Accountable, Flexible, Efficient, Transportation Equity Act: A Legacy for Users (SAFETEA-LU). This report documents a careful review of the original measures and identifies new measures intended to fill gaps created by recent adjustments to the program in light of new legislation, emerging programs, and refinement of program goals and activities. The result of this is an updated performance assessment document tracking continued progress in meeting each of the RWMP objectives.

Ideally, performance measurement will be carried out on a regular, periodic basis, perhaps bi-annually, focusing on improvements that can be assessed against a baseline of performance established in prior evaluations. By maintaining consistency in the measures of performance across the years, a more complete, long-term picture of RWMP performance can be obtained. However, with the sunset of SAFETEA-LU and implementation of Moving Ahead for Progress in the 21st Century Act (MAP-21), the past two years have seen several major changes in RWMP direction and objectives. These changes, as well as evolving external conditions that also impact program performance, have resulted in modifications to the performance measures that were established for the initial assessment five years earlier. This report retained as many measures used previously as possible, consistent with recent programmatic changes, along with the addition of several new measures to allow assessment of progress toward the recently emerging RWMP objectives.

Since 2009, various other programmatic efforts have come to the foreground, and new activities have been started. For example, the Maintenance Decision Support System (MDSS) is reasonably widely accepted in the road weather management community. *Clarus* is operational as a truly national system of environmental sensing stations. The traffic management community has been engaged through the Weather Responsive Traffic Management (WRTM) program through identification of best practice strategies, development of modeling and simulation tools, creation of training modules, and targeted outreach. The last few years have also seen the development of human factors guidelines and real-world implementation of WRTM strategies. Building on the success of the previous efforts, the RWMP is now focused on supporting the continuing maturity of the capabilities of road weather management, increasing the level and sophistication of deployment, and forging new areas of research.

Updated Performance Measures

The final list of performance measures for 2012 was updated based on an internal review of RWMP activities as well as examining external needs and performance-related initiatives that affect the program. Table ES-1 is organized by the seven program objectives and contains measures that remain unchanged from 2009, measures modified from those used in 2009, and several new measures reflecting current RWMP priorities. The resulting twenty two (22) measures characterize the performance of the program across the seven objectives.

Table ES-1. RWMP Performance Measures for 2012

RWMP Objectives	Final 2012 Performance Measures
Build partnerships with transportation and weather communities	1. Number of agencies participating in road weather research and development (R&D) projects. 2. Number of agencies participating in and benefiting from Road Weather Management stakeholder meetings/workshops. 3. Number of organizations/groups where FHWA is represented (National and International).
Raise road weather management knowledge and capabilities across the transportation industry	4. Number of agencies and attendees who have taken any of the training courses sponsored by the RWMP. 5. Number of agencies and participants in road weather management webinars. 6. Number of meetings, site visits or venues where road weather management presentations/briefings were made. 7. Number of hits/visits to RWMP websites.
Advance the collection, processing & distribution of fixed and mobile road weather observations	8. Number of transportation agencies participating in road weather data sharing activities. 9. Number of transportation agencies that subscribe to road weather products and services. 10. Number of agencies collecting mobile observations of road weather data from vehicle fleets. 11. Number and distribution of fixed Environmental Sensor Stations (ESS).
Increase the use of weather-enabled decision-support tools and dynamic mobility applications	12. Number of agencies adopting MDSS technologies and methods. 13. Number of agencies using other weather-related decision-support tools. 14. Number of agencies using weather-responsive traffic-related analysis, modeling, simulation and decision-support tools.
Develop and support operational deployment of advanced road weather management strategies	15. Number of States disseminating advisory weather and road weather information to travelers. 16. Number of agencies using control and treatment strategies during weather events.
Improve overall system performance during weather events	17. Reductions in agency costs of weather-related maintenance and operations activities. 18. Reduction in number and types of fatalities and crashes attributed to adverse weather nationally. 19. Reduction in the extent of capacity losses and delays due to fog, snow, and ice events including freight. 20. Increase in travel time reliability or decrease in variability due to road weather management strategies during adverse weather scenarios. 21. Reduction in number of tons of salt or chemical usage in the U.S. normalized by winter severity index.
Engage the climate change community in maintenance and operations	22. Number of public agencies meeting “INVEST” and/or sustainability criteria related to road weather management.

Source: Battelle

The measures used to assess the performance of the RWMP reflect both quantifiable outputs (e.g., number of agencies that have acquired an MDSS, or the number of training programs conducted) and qualitative outcomes (e.g., the extent to which agencies are using MDSS more effectively throughout their jurisdiction, or the proactive incorporation of road weather information by transportation operators in decision making and the benefits experienced from these activities). Some of the RWMP objectives can be assessed quite adequately with quantitative output measures. For example, assessing success at building partnerships can be measured by identifying the number of agencies that are working together on road weather projects, jointly developing new operational strategies, and participating in joint-agency meetings and workshops. Other objectives however, such as enhancing road weather knowledge and capabilities are more difficult to capture solely with quantitative output measures, such as attendance at training courses or RWMP website visits. It is assumed that actions taken by the RWMP to engage stakeholders and encourage their participation in various program activities will translate into the desired qualitative benefits, such as more effective use of tools or, ultimately, enhancements to traveler safety and mobility. A challenge for performance measurement is to gather the kinds of data that can support these more intangible qualitative outcomes; namely, measures that assess impacts and benefits.

RWMP Performance and Results

Objective 1: Build Partnerships with Transportation and Weather Communities. Since 2010, the RWMP has continued to support symposia and partnership-building and recently has expanded coverage to emerging topics of interest, such as social media, WRTM and connected vehicle technologies. Participation now includes a broader mix of stakeholders, and progress has been achieved in terms of increased attention to weather in national forums such as TRB and pooled fund activities. Key partnerships are leading to important tangible accomplishments, such as the transition from *Clarus* to Meteorological Assimilation Data Ingest System (MADIS).[1]

Performance measurement for this program objective primarily focuses on output measures, such as extent of partnerships established, growth in stakeholder participation, and increased recognition and acceptance by the stakeholders of the leadership role played by the program as summarized in Table ES-2 below.

[1] On June 30, 2013 *Clarus* was shut-off in preparation for MADIS transition.

Table ES-2. Summary of Objective #1 Performance Advances

PM-1: Number of agencies participating in road weather R&D projects
• Over 45 public agencies have participated in the *Clarus* System. • 8 State DOTs have conducted *Clarus* demonstrations while 7 State and local DOTs have participated in *Clarus* Broad Agency Announcements (BAAs). • 14 public agencies have been involved in weather responsive traffic management including TMC weather integration, human factors, TrEPs, and WRTM implementation. • 3 State DOTs have been involved in integrated mobile observations /CV, 5 agencies with MDSS, and 4 State DOTs with the Western State Rural Transportation Consortium.
PM-2: Number of agencies participating in and benefiting from Road Weather Management stakeholder meetings/workshops
• Available evaluations from workshops/meetings show very positive feedback from the attendees. • Demonstrated trend of increasing yearly levels of State participation in Stakeholder meetings (MDSS, *Clarus*, RWMP, and WRTM).
PM-3: Number of Organizations/Groups where FHWA is Represented (National and International)
• In four self-reported cases RWMP has a leadership role in setting the agenda and strategic direction of the organization/group. • In nine self-reported cases it is a member of an organization/group. • Organizational participation is diverse including involvement in AASHTO subcommittees, TRB committees, ITS America, and the American Meteorological Society (AMS).

Source: Battelle

Overall, the three performance measures reveal strong engagement and partnerships fostered and supported by the RWMP. The performance measures illustrate the depth and breadth of State DOT engagement across all of the program's major initiatives. Additionally, the stakeholder meetings continue to be a valuable forum for information exchange in the road weather management community evolving over time from *Clarus* and MDSS focused meetings to take on a broader road weather management agenda. The breadth and the leadership role of the RWMP continues to grow across the various organizations/groups.

Objective 2: Raise Road Weather Management Knowledge and Capabilities across the Transportation Industry. Providing training, education, technical assistance, technology transfer, and resources to assist States and partner transportation agencies in more fully taking weather into account in their management and operational responsibilities has been an important component of the RWMP since its inception. Since 2000, the RWMP has produced and made available through their website various outreach documents, technical reports and papers. In 2012 this objective was broadened to focus on expanding and strengthening the range of road weather capabilities throughout the transportation industry. A summary of objective 2 performance (by measure) is provided in Table ES-3 below.

Table ES-3. Summary of Objective #2 Performance Advances

PM-4: Number of public agencies and attendees who have taken any of the training courses sponsored by the RWMP
• Since the last performance measure update, in order to reach a larger audience, the information for some online training courses has been more widely publicized. • Courses have shown consistent or increased levels of participation since being offered.
PM-5: Number of agencies and participants in road weather management webinars
• Since first webinar in 2006, the program has experienced consistently high participation levels. Between 2006 and 2009, four webinars hosted with 543 participants. In 2012 alone, four webinars held with 479 participants. This increase in participation shows a high level of interest in the webinars even after a two year lull.
PM-6: Number of meetings, site visits or venues where road weather management presentations/briefings were made
• From 2009 to 2012, RWMP presented in every TRB Annual Meeting, AMS Annual Meetings, TRB-sponsored International Conference on Winter Maintenance and Surface Transportation Weather, Aurora, Clear Roads, ITS-Irvine, Connected Vehicle Pool Fund Study, ITS America 2012, and National Committee of the USA World Road Association (PIARC) – Winter Maintenance Technical Committee. • Exact numbers on the measure are difficult to obtain given the diversity of engagements to which RWMP is invited to participate.
PM-7: Number of hits/visits to RWMP websites
• In 2012, 68 percent of evaluation survey respondents (conducted after annual stakeholder meeting) had visited the RWMP website. Of these respondents, 71 percent had downloaded material. These indicate a high degree of use and awareness of the website. • Summary statistics on usage over the April 2012 to March 2013 timeframe indicate an average monthly growth rate of the following: hits (14 percent), page views (9 percent), and visitors (5 percent).

Source: Battelle

The measures represent the program's high level of activity to support raising road weather knowledge and awareness. Attendance in training activities, the use of the RWMP websites and the publication and presentation outputs of the program staff have enabled the RWMP to successfully meet this objective. Unfortunately, these measures only reflect the delivery of training, tools, and guidance to the community. While continued participation and use of these resources is a suitable proxy for interest, future efforts under this objective need to address the improvements in capability and performance enabled by these resources. This may be accomplished by providing a response form for all future resources posted on the RWMP website requesting feedback on the usefulness and efficacy of the resource, along with how they have been used.

Objective 3: Advance the Collection, Processing and Distribution of Fixed and Mobile Road-Weather Observations. The idea of utilizing passenger and fleet vehicles as weather observation probes is tantalizing due to the potential to increase the coverage and quality of the road weather observations. Already, mobile data have been reported to the *Clarus* system by several States including Minnesota, Missouri, and Nevada. Another component of this objective is to increase the use of both fixed and mobile observation in agency decision-making, traveler advisories and weather forecasting. Recent RWMP efforts in this area have included supporting *Clarus* Multi-State Demonstrations and funding eight (8) application development projects through a Broad Agency Announcement (BAA). A summary of these efforts is included in Table ES-4 below.

Table ES-4. Summary of Objective #3 Performance Advances

PM-8: Number of transportation agencies participating in road weather data sharing activities
• 2006 to 2008 – number of agencies contributing ESS increased from 3 to 33 with a total of 1,700 ESS reporting to the *Clarus* System. • 2008 to 2013 – number of agencies increased from 33 to 49 with a total of 2,437 ESS reporting to *Clarus.* • Results represent a 45 percent increase in the number of agencies and a 43 percent increase in the number of sensor stations in the four years since performance measurement.
PM-9: Number of transportation agencies that subscribe to road weather products and services
• Access to most of the sources included in the survey has increased slightly or leveled off over the past six years. • 2013 Survey reveals high usage of road weather products (100 percent use National Weather Service (NWS), 93 percent use their agency sensors, ~80 percent use private sector sources, 63 percent use national observation systems like *Clarus*. • The increased access to sources implies a widespread awareness of weather products and information sources along with the increasing relevance of these products in State transportation operations.
PM-10: Number of agencies collecting mobile observations of road weather data from vehicle fleets
• About quarter of DOTs said none of their vehicles collect data. • 3 out of 4 State DOTs are using road weather data collection strategies in some of their vehicles. • Potential for DOTs that are collecting some mobile data from some of their vehicles to increase that with a higher proportion of their vehicle fleets.
PM-11: Number and distribution of fixed Environmental Sensor Stations (ESS)
• As of June 2008, there were an estimated 2,499 ESS of which 2,017 were part of a RWIS. • As of 2012, agencies had connected 2,435 ESS to *Clarus*.

Source: Battelle

Activities under objective #3 have been very successful for the program. Fixed observations through Road Weather Information System (RWIS) are widely and routinely used across the country in operations. While improvements are still possible in the level and the quality of use of RWIS data nationally, the program has rightly shifted focus towards advancing the collection, processing and distribution of mobile observations. However, with the decommissioning of *Clarus* and its subsequent reincarnation as an operational environment under MADIS and a research environment as part of the Weather Data Exchange, the program needs to ensure that the collection, processing and distribution of quality-checked fixed observations do not suffer.

Objective 4: Increase the Use of Weather-based Decision-support Tools and Dynamic Mobility Applications. Making systems management and operations-related decisions based on road weather observations and forecasts continues to be a challenge for many State and local agencies. The impact of weather on traffic conditions is not simple or homogenous. Since the beginnings of the RWMP, it has been working with researchers and universities in the US and abroad to collect and analyze data and develop models and tools to improve the analysis, modeling and prediction of traffic flow in all types of weather conditions. The RWMP also continues to support MDSS. Since the creation of the functional prototype, various private sector providers now offer MDSS capabilities to the States. Measures under this objective trace the adoption of three categories of decision-support: (1) MDSS for winter maintenance, (2) other weather-related operations, and (3) traffic modeling and analysis as highlighted in Table ES-5 below.

Table ES-5. Summary of Objective #4 Performance Advances

PM-12: Number of agencies adopting MDSS technologies and methods
• 2013 – Almost three-quarters of State DOTs said they either have in place, are considering, or need an MDSS with 26 percent reporting they don't need an MDSS. • 2008, five State DOTs reported regular operational use of an MDSS system, 2013 – seven State DOTs reported use. • Results suggest that usage of MDSS technology has expanded over the past five years.
PM-13: Number of agencies using other weather-related decision-support tools
• Most State DOTs (96 percent) are offering traveler information to assist drivers, especially during weather events. • Majority of State DOTs are using more than one tool, with over three-quarters (77 percent) report using three or more of them. • Evidence suggests State DOTs are using a wider array of decision support tools now to support their road weather management practices, and the use of some of these tools is becoming increasingly widespread.
PM-14: Number of agencies using weather-responsive traffic-related analysis, modeling, simulation and decision-support tools
• Usage of Traffic analysis models and tools is very low among the responding State DOTs (83 percent). • Majority of DOTs report using no traffic models (86 percent). • A few of the respondents said they were unaware whether or not their State DOT was using any of these tools.

Source: Battelle

As the performance measures indicate, there has been a clear growth in the adoption of MDSS around the country from 2008. This is a positive step towards reducing maintenance costs while providing enhanced levels of service to the travelers. States also reported using various other decision tools as part of their road weather operations. While it is not clear what tools they meant, the categories indicated by the respondents are certainly on track with the goals of the RWMP. The next big challenge for the program is to encourage a more analytic approach to road weather through the use of analysis, modeling and simulation tools.

Objective 5: Develop and Support Operational Deployment of Advanced Road Weather Management Strategies. The RWMP continues to review current practices, document the benefits of existing approaches, and identify needs, such as strategies applicable for use on arterials, freeways, and rural roads. In 2011, a comprehensive set of WRTM improvements was compiled by the RWMP. The report details what strategies exist, where they have been used, the benefits realized, and how to improve, implement, and evaluate them as part of their operations. Similarly, best practices for RWMP were compiled in 2013. These provide discrete examples of operational deployment of advanced road weather strategies. At a metropolitan level, the Operations and Efficiency Index (OEI) provides a good summary of deployment but does not get into details of the strategies. While the OEI provides a high-level summary and is a good national-level indicator, the measures discussed in Table ES-6 assess the overall level of deployment of these strategies across the nation at a greater level of detail.

Table ES-6. Summary of Objective #5 Performance Advances

PM-15: Number of States disseminating advisory weather and road weather information to travelers
• 80 percent of agencies report road surface information on Dynamic Message Signs (DMS) at least in some locations within the State, 52 percent share weather information on Twitter, 50 percent share weather and road weather information on Highway Advisory Radio (HAR). • Current survey results show further progress since 2007 in the deployment of road weather information to the traveling public, though direct comparisons are difficult given differences in the surveys conducted in 2007 and 2013 and the response rates to these surveys.
PM-16: Number of agencies using control and treatment strategies during weather events
• Traffic incident management practices in response to inclement weather are most widely deployed of all strategies surveyed (Close to 88 percent of agencies). • Adjusting signal timing at intersections in response to weather remains relatively rare (21 percent). • Use of technology for road closures (52 percent), temporary restrictions based on ESS (50 percent), varying speed limits (28 percent), and adjusting ramp meters (23 percent) are used by States in appropriate locations. • Results indicate substantial room for further adoption of these kinds of road weather operational strategies across the States.

Source: Battelle

The operational deployment of advisory, control and treatment strategies is growing nationally. Survey responses from the State DOTs indicate high awareness and utilization of several of these strategies. Importantly, there is room for improvement in meeting this objective. States report several strategies which are partially deployed. Encouraging the continuous deployment and refreshment of these strategies is important.

Objective 6: Improve Overall System Performance during Weather Events. Assessments of State DOT performance with regard to their responses or actions during adverse weather, and particularly efforts to compare performance across different locations, agencies or time periods, raise a methodological question of how to control for differences in the type and severity of the weather events. The objective is to understand and measure performance in a way that reflects the effectiveness and impacts of the agency's actions, but those effects are significantly influenced by the weather itself. As the discussion of the performance measures under this objective illustrate (Table ES-7), the performance of RWMP can be measured most appropriately not by overall national-level numbers but by isolated success stories throughout the nation.

Table ES-7. Summary of Objective #6 Performance Advances

PM-17: Reductions in agency costs of weather-related maintenance and operations activities

- Case studies showed that winter maintenance costs decreased as the use of weather information increased or its accuracy improved.
- Use of MDSS is showing substantial benefits and reductions in costs. For example, Indiana reported a cost reduction (per winter) of $1.3 million (58,274 hours) in overtime and $12 million in salt.
- Treatment actions such as anti-icing and pre-wetting have also demonstrated significant material and costs savings.
- Overall, the number of positively evaluated MDSS systems continues to grow.

PM-18: Reduction in number and types of fatalities and crashes attributed to adverse weather nationally

- Low visibility and other active warning systems, as well as anti-icing have demonstrated significant benefits. For example, an automatic bridge anti-icing system in Utah reduced crashes by 64 percent.
- Nationally, the number of fatal crashes occurring during inclement weather is generally on a decreasing trend similar to overall crashes (irrespective of the cause of incident). The rate of decrease however is slower for weather-related crashes compared to crashes as a whole.

PM-19: Reduction in the extent of capacity losses and delays due to fog, snow, and ice events including freight

- Active warning systems and traveler information systems have demonstrated benefits on traffic flow. For example, a low visibility warning system in Salt Lake City, Utah reduced speed variability by 22 percent and increased speed by 11 percent.

PM-20: Increase in travel time reliability or decrease in variability due to road weather management strategies during adverse weather scenarios

- Some early reliability benefits of traveler information during weather conditions have been reported. For example, in Idaho, 80 percent of motorists (responding to a survey) who used the pre-trip road condition system indicated that the information they received made them better prepared for road-weather conditions.
- SHRP2 and other efforts will increase the data available to quantify the measure.

PM-21: Reduction in number of tons of salt or chemical usage in the U.S. normalized by winter severity index

- Use of a Winter Weather Severity Index (WSI) has gained recognition as a way to gauge relative severity of winter weather across geographic regions.
- Several States are currently developing methodologies for using WSIs.
- Implementation of road weather management tools like MDSS and treatment technology such as deicing, anti-icing methods help agencies optimize material use. For example, use of MDSS in Indiana resulted in statewide savings of $9,978,536 (188,274 tons) in salt usage and $979,136 (41,967 hours) in overtime compensation from the previous winter season.

Source: Battelle

An increasing number of case studies point to progress in using best practices for achieving safety, mobility, and productivity goals around the country. Since RWMP is not an operating or a rule-making agency, the primary pathway to influence overall system performance is to encourage the adoption of best practices and support robust evaluations of them. Experiences like Indiana DOT's use of MDSS or the safety benefits offered by low-visibility warning systems are proof that these systems work and have the desired impacts. Aggressive management of salt use, not only from a cost-saving standpoint but also from an environmental sustainability viewpoint, is starting to emerge as a priority at State levels but consistent approaches to measure and evaluate their performance longitudinally across winters are rare.

Objective 7: Engage the Climate Change Community in Transportation Maintenance and Operations. Climate change effects can be separated into two general categories based on whether the effect is part of a climate trend (e.g., increasing annual average air temperatures) or is associated with a distinct climate event (e.g., storm, flood, drought, heat wave), as these different categories of effects will necessitate different types of operational responses by transportation agencies. Road Weather Management, as on operational strategy, is obviously a core component of the adaptation strategy related to climate events. As the frequency, severity and the probability of occurrence at particular locations change, a robust RWMP is essential. Less obvious however are the system maintenance and operations changes associated with climate trends which affect how agencies budget and staff their road weather management activities. Performance measures continue to be refined in this area. Currently, the following performance measure (in Table ES-8) describes the role that road weather management plays in climate change adaptation and sustainability.

Table ES-8. Summary of Objective #7 Performance Advances

PM-22: Number of public agencies meeting "INVEST" and/or sustainability criteria related to road weather management
• There is a high number of States developing and implementing RWMP as well as fully or partially deployed an MDSS. • There is a mix in the level of goal setting and progress/performance measurement occurring across States. • Some best practices for snow and ice control exist but they are not uniform across the nation.

Source: Battelle

Overall, State DOTs, especially the northern-tier States, meet many if not all of the programmatic criteria identified in INVEST such as having a road weather program, having RWIS and the use of MDSS. The major weaknesses pertain to performance measurement, use of standard operating practices (SOP) and material management, which are more sporadic in their use across the nation.

Conclusions

This most recent assessment of progress across the country in meeting the RWMP objectives shows continuing adoption of advanced technologies, decision support tools, and more effective use of advanced road weather management strategies. However, there is ample room for improvement. Much of the attention in road weather management to date has been focused on dealing with winter weather challenges, and attention is only now beginning to include strategies for addressing non-winter weather problems, including rain, flooding, wind, fog, and weather effects on road maintenance and construction activities year round. Given the introduction and recent deployment of new tools and technologies for road weather (e.g., non-winter Maintenance and Operation Decision Support System – MODSS), those States willing to make early investments and take risks deploying these new approaches have done so through pilot projects and partial deployments in order to see whether they were cost effective and beneficial to their operations. Other States are taking a wait-and-see approach to these deployments, or are reluctant to make new investments in an environment of very constrained resources. Thus, there remains room for the RWMP to continue to encourage and support where possible moving partial deployments toward more complete statewide deployments, and convincing other State DOTs to adopt proven strategies for effectively managing and operating their systems under a range of road weather conditions.

A little over half the State DOTs responded to the State survey used in this current study, and they were all concentrated in the northern half of the country. This presumably reflects the perceived primacy of winter weather among State DOT operational concerns as they relate to weather effects on their transportation systems, as well as the historical focus of the RWMP. In the future, the RWMP will need to explore more effective ways of drawing the southern tier State DOTs into their program by further expanding tools and resources toward supporting non-winter weather operations and emphasizing the importance of integrating weather into operations in these settings. From a performance assessment standpoint, it is important to broaden the measures to address outputs and outcomes of RWMP activities across the full national range of weather types and environments.

Recommendations

Next steps in providing improved performance measurement should focus on qualitative outcome indicators of growth in capability, knowledge and skill that lead to increases in public safety and mobility. These recommended steps include the following:

- ***Introduce Performance Measurement as a Topic During Stakeholder Meetings:*** Include this as a topic at stakeholder meetings at which the participants can share their perspectives on how to better assess these more elusive attributes of performance. The RWMP could then seek to encourage the adoption of a common, consistent set of qualitative output indicators across the States. In addition, the RWMP should offer guidance to the States regarding the kinds of data that need to be routinely collected and maintained in order to support long-term assessments.
- ***Work with Agencies to Agree on Best Practices:*** Measuring safety benefits is particularly elusive and difficult due to the relative rarity of crashes and fatalities, the lack of data on the role of weather in crashes, and the need to extend data collection and evaluation coverage over a sufficient period of time to be able to assemble sufficient data. The RWMP should work with the States and Federal traffic safety agencies to agree on a best practices approach to assessing the safety benefits of the RWMP.

- ***Work with State DOTs to Develop Approach for Controlling for Weather Variability :*** The RWMP should work with the State DOTs to develop a common and consistent approach to controlling for variability in the type, occurrence and intensity of weather events over time in order to be able to more reliably assess the effects of operational actions on system performance.
- ***Work with Related Programs to Increase Awareness of RWMP Tools and Resources:*** Recent and emerging new legislation and research/action programs have direct relevance to the RWMP's efforts to assess their program performance. These new initiatives not only convey their own need for performance assessment, but also offer another mechanism to support innovation in measurement and encourage the incorporation of weather as a critical factor in affecting transportation program performance. Examples that have been mentioned in this report include the Section 1201 rule of SAFETY-LU that calls for real-time information programs at the State level on all interstates by November 2014, and MAP-21 that is providing funding to update transportation infrastructure and improved operations and performance. Another is the SHRP2 research program aimed at aging infrastructure, congestion and safety and offering solutions to improve transportation operations. The connected vehicle initiative offers clear opportunities to incorporate weather into an important operational program that will directly impact safety and mobility. The RWMP should work closely with these kinds of programs to leverage building greater awareness of the importance of road weather considerations and promotion of the more effective use of research, tools and other resources.
- ***Maintain Core Set of Measures for Evaluation:*** This report addressed the update to the RWMP performance assessment program in what is expected to be an on-going effort to document goal attainment. Going forward the RWMP should aim to establish a core set of measures that are applied consistently over time in order to support effective longitudinal analysis of program growth and performance. It is inevitable that program goals and objectives will be adjusted from time to time and that new external programs and activities will influence RWMP outcomes in unpredictable ways. Therefore, a subset of measures will need to be revised or new measures added to keep pace, but to the extent possible it will be advantageous to keep a core set of measures consistent for the duration of the program.

Finally, it is important to emphasize that, notwithstanding a variety of opportunities that can be identified where the RWMP can make further improvements, the results from this update study on program performance demonstrate substantial and continuing progress. Going forward, the RWMP, in collaboration with related programs, can use the results of these assessments to further encourage all State DOTs and transportation agencies to proactively bring weather information, tools and resources actively to bear in their operations, especially those States and agencies that have held back due to concerns with costs and risks. The evidence now overwhelmingly points to the advantages and potential cost savings associated with the adoption of road weather management strategies, both for DOT operations and for the traveling public.

Chapter 1 Introduction

Background

Guided by its founding goals set out in the Safe, Accountable, Flexible, Efficient, Transportation Equity Act – A Legacy for Users (SAFETEA-LU) legislation in 2005, the Road Weather Management Program (RWMP), within the Office of Operations of the Federal Highway Administration (FHWA) at the U.S. Department of Transportation (USDOT), has initiated several programs, projects and activities targeted at State and local agencies. Each has resulted in measurable outputs and outcomes that reflect the accomplishments and benefits of road weather management across the country. As RWMP products, services and activities started to become widespread, RWMP began a formal process in 2006 to measure the success of the program and provide evidence of the extent of achievement of the goals set in SAFETEA-LU.

The framework for establishing viable performance metrics is complex, since the pathways by which the RWMP and exogenous factors affect performance outcomes are themselves complex. Through a rigorous stakeholder engagement process[2] involving literature reviews, stakeholder outreach through Requests for Information (RFIs) and an in-person stakeholder workshop, a short list of manageable measures was developed in 2008. The final list of measures was selected by the RWMP as key indicators of success.

Challenges in Measuring RWMP Performance

A challenge for performance measurement is to isolate and measure the independent impacts attributable to the RWMP from the aggregate impacts that are contributing to goal attainment.

Goal attainment can potentially be caused by activities and factors that occur outside the RWMP. While significant impacts will be caused as a direct consequence of the RWMP, some aspects of goal attainment may result from indirect impacts channeled through other agencies and programs that operate concurrently with the RWMP. For example, one of the main RWMP elements has been to foster a collaborative research and applications agenda in the field of road weather management. Other Federal, State and private agencies and organizations undertake activities independent of the RWMP that also may affect progress toward achievement of the SAFETEA-LU goals. These activities can complement or reinforce the RWMP's activities. Thus, a challenge for performance measurement is to isolate and measure the independent impacts attributable to the RWMP from the aggregate impacts that are contributing to goal attainment.

[2] U.S. Department of Transportation, Federal Highway Administration. (2008). Road Weather Management Performance Metrics. Report No.: FHWA-JPO-08-039. EDL No.: 14420. (April).

By breaking down the measures into their component indicators and collecting data on RWMP products, activities and services, the measures were quantified and documented in August 2009.[3] Various data sources were used including:

- Intelligent Transportation Systems (ITS) Deployment Statistics
- ITS Benefit-Cost Database
- Selected data and program records from the RWMP
- Focused RWMP sponsored surveys/interviews of State DOTs.

With the sunset of SAFETEA-LU, the passage of Moving Ahead for Progress in the 21st Century Act (MAP-21), and the evolution of RWMP in the past few years, FHWA initiated an update of its performance measures. In fact, performance measurement of programs, projects and activities has emerged as an important element of the new authorization (MAP-21) lending more importance to this study. The FHWA Office of Operations has also undertaken various benchmarking activities to assess the state of transportation systems management and operations in the country. Road Weather Management has been an important component of these activities. All of these activities contribute to a need to revisit, update and refine the performance measures evaluated in 2010.

Project Scope and Objectives

This project updates the performance measures using information available in 2012. The focus areas of this update include:

- Reviewing the direction and evolution of the RWMP and identifying major accomplishments since 2009.
- Reviewing existing measures for their continued suitability, strengths, and weaknesses for evaluating program performance.
- Determining changes to the baseline conditions for existing measures using updated or new data sources.
- Incorporating within existing or through new performance measures:
    - Reliability and other operations measures that have been adopted by the Office of Operations and the Strategic Highway Research Program 2 (SHRP2) research program
    - Operations Efficiency Index (OEI) measures for the top 40 metropolitan areas.
- Identifying refinements necessary to the existing performance measurement framework and developing a plan to quantify the measures.
- Quantifying all existing and new performance measures using current data to create a 2012 RWMP performance assessment report.

[3] U.S. Department of Transportation, Federal Highway Administration. (2009). Road Weather Management Performance Metrics: Implementation and Assessment. Report No.: FHWA-JPO-09-061. EDL No.: 14492. (August).

In order to achieve these objectives, the project is divided into five tasks as shown in Figure 1-1. This report documents all these tasks undertaken as part of this project.

Figure 1-1. Project Methodology

Organization of the Report

The remainder of the report includes the following sections:

- Chapter 2 describes the evolution of the RWMP and its implications for program performance;
- Chapter 3 defines the performance measures selected for quantification in 2012;
- Chapter 4 presents the performance measures organized by RWMP objectives;
- Chapter 5 provides a high-level summary assessment of performance for the program across all objectives using data described in Chapter 4;
- Chapter 6 explains the major conclusions and next steps derived from this effort; and
- Appendix A includes the detailed survey data collected from State DOTs as part of this study.

This page intentionally left blank.

Chapter 2 Evolution of RWMP Performance Measures

The following sections discuss the performance measures originally identified in 2009 as well as the updated RWMP measures, including descriptions of elements of the program evolution that are driving the need to rethink and supplement the previous measures. Figure 2-1 provides a timeline of RWMP performance measure development, quantification, and updating.

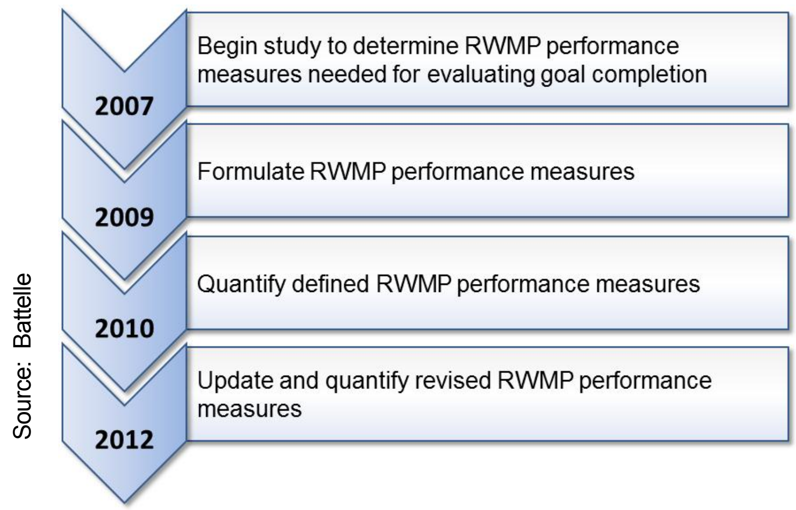


Figure 2-1. Development and Quantification of RWMP Performance Measures

RWMP Activities that Affected Performance Measurement between 2006 and 2009

The years 2006 to 2009 led to several major initiatives coming to fruition for the RWMP. Significant progress in stakeholder engagement, development of national road weather observing system (*Clarus),* deployment of Maintenance Decision Support Systems (MDSS), and weather responsive traffic management (WRTM) led to an increased visibility of road weather as an important program within transportation systems management and operations. During this time, activities under the program were organized under the following objectives[4]:

[4] Chapter 2 in the U.S. Department of Transportation, Federal Highway Administration. (August 2009). Road Weather Management Performance Metrics: Implementation and Assessment. Report No.: FHWA-JPO-09-061. EDL No.: 14492.

1. Develop a national, open observing system that promotes data sharing to support weather observing and forecasting, and support transportation operations.
2. Develop resources and training methods to assist State and local partners in the deployment of road weather management tools.
3. Advance the state-of-the-practice by developing proactive solutions and disseminating information on adverse weather.
4. Foster a collaborative, comprehensive, and dedicated surface transportation weather research program.

Table 2-1 highlights the major initiatives under each objective during this time. The reader is directed to the previous performance assessment report, *Road Weather Performance Metrics: Implementation and Assessment* (FHWA-JPO-09-061)[5], and the FHWA RWMP website (http://ops.fhwa.dot.gov/weather/) to learn more about the accomplishments under each initiative.

Table 2-1. Ongoing and Previous Initiatives under the SAFETEA-LU Driven Objectives

Objective	Major Activities/Initiatives/Accomplishments
1. Develop a national, open observing system	• WIST Initiative. • COMET. • Cooperative Agreement between FHWA and National Oceanic and Atmospheric Administration (NOAA). • Surface Weather Data Requirements for the National Highway System. • Road Weather Information System (RWIS) Standards – Siting, Calibration, and Communication. • *Clarus* Initiative.
2. Develop resources and training methods	• Best Practices for Road Weather Management. • NHI course of Road Weather Management. • Snow Expo. • Road Weather Resource Identification (RWRI) Database. • MDSS Road Show.
3. Advance the State-of-the-practice	• MDSS Functional Prototype Development, implementation and evaluations. • Weather Responsive Traffic Management. • Early activity on vehicle infrastructure integration.
4. Foster a collaborative research program	• TRB Surface Weather Transportation and Winter Maintenance Committee. • AMS Policy Forum. • Pooled Fund Studies (PFS) and Cooperative Research Programs (Aurora, Clear Roads, Traffic Management Centers (TMC), Snow and Ice Pooled Fund Cooperative Program (SICOP), Subcommittee on Maintenance [SCOM]).

Source: FHWA-JPO-09-061

[5] U.S. Department of Transportation, Federal Highway Administration (2009). Road Weather Management Program Performance Metrics: Implementation and Assessment. Report No.: FHWA-JPO-09-061. EDL #14492 (August).

Measuring Program Performance from 2006 to 2009

Using a rigorous stakeholder engagement process[6] involving literature reviews, stakeholder outreach through RFIs and an in-person stakeholder workshop, a short list of manageable measures was developed to measure program performance. Table 2-2 illustrates the final list of measures selected by the RWMP as key indicators of success.

Table 2-2. 2009 RWMP Performance Measures

Goal 1:	**Maximize use of available road weather information and technologies.**
1.1	Number or percentage of transportation agencies that use road weather information and decision support systems (based on current or forecast information) for making advisory, control and treatment decisions.
1.2	Number or percentage of travelers who use road weather information for making travel decisions (both pre-trip and en-route).
1.3	Number of Environmental Sensor Stations (ESS) deployed and used by transportation agencies to support decision-making (normalized by total area or length of road network).
Goal 2:	**Expand road weather research and development (R&D) efforts to enhance roadway safety, capacity and efficiency while minimizing environmental impacts.**
2.1	Number of agencies participating in and benefiting from road weather R&D projects.
2.2	Percentage of time roadway meets safety and capacity level of service (LOS) standards (i.e. V/C ratio, etc.) during and after weather events (normalized by the frequency/intensity of winter events).
2.3	Reduction in agency costs (i.e. labor, equipment, and materials) due to adoption of maintenance and operations decision-support systems for road weather management.
2.4	Reduction in user costs (i.e. delay, crashes, vehicle operating costs, emissions, salt damage) due to improved road weather advisory, control and treatment strategies.
Goal 3:	**Promote technology transfer of effective road weather scientific and technological advances.**
3.1	Number of agencies/individuals visited or contacted through technology transfer, training and outreach efforts.
3.2	Rate of adoption of road weather management technologies (e.g., decision-support systems) by agencies that participated in workshop or training activities.
3.3	Number of road weather management technology development, testing and deployment activities initiated through public or private sector based on identified operational needs.
3.4	Number of road weather technologies developed through public-private and/or public-public partnerships reaching operational deployment.

Source: FHWA-JPO-09-061

[6] U.S. Department of Transportation, Federal Highway Administration. (2008). Road Weather Management Performance Metrics. Report No.: FHWA-JPO-08-039. EDL No.: 14420. (April).

Evolution of the RWMP from 2009 to 2012

Since 2009, various other programmatic efforts have come to the foreground, and new activities have been started over the past two years. For example, MDSS is reasonably widely accepted in the road weather management community. *Clarus* is operational as a truly national system of environmental sensing stations. The traffic management community has been engaged through the WRTM program through identification best practice strategies, development of modeling and simulation tools, creation of training modules, and targeted outreach. The last few years have also seen the development of human-factors based guidelines and real-world implementation of WRTM strategies. Building on the success of the previous efforts, the RWMP is now focused on supporting the continuing maturity of the capabilities of road weather management, increasing the level and sophistication of deployment, and forging new areas of research.

Since the last assessment[7], the RWMP has continued some activities and ventured into new research areas, as illustrated by the conceptual framework in Figure 2-2. The conceptual framework, which emerged from a stakeholder policy forum sponsored by the RWMP in Washington DC on November 8-9, 2010, builds on the successes of the existing activities like *Clarus* and MDSS. Stakeholders in the policy forum argued for a comprehensive program approach tackling traffic data, weather forecast models, observing systems, decision-support tools, and institutional frameworks to achieve societal goals and benefits.

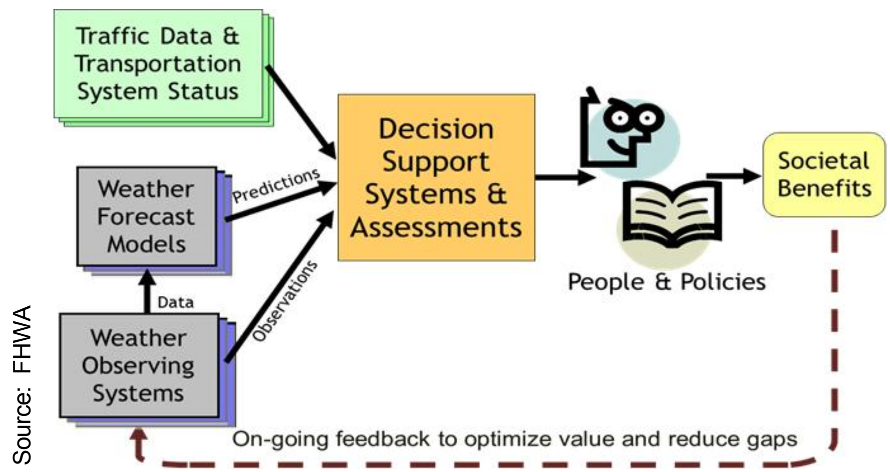


Figure 2-2. Conceptual Framework for the RWMP

The framework was used as one of the bases for updating and changing the RMWP objectives from 2009 to what they are today (as shown in Table 2-3). The orange-colored boxes indicate significant differences from the 2009 objectives while the green boxes indicate a general continuation of the 2009 objectives. While the broad objective of advancing the state-of-the-practice by developing proactive solutions continues to play a role in 2012, the RWMP has added a specific focus on the role of road weather observations in decision-support tools. Importantly, with the *Clarus* System representing a

[7] Chapter 2 in the U.S. Department of Transportation, Federal Highway Administration. (2009). Road Weather Management Performance Metrics: Implementation and Assessment. Report No.: FHWA-JPO-09-061. EDL No.: 14492. (August).

significant achievement and concluding its operational phase, the program has moved towards exploring the capability to collect, synthesize and use mobile road weather observations. In many ways, this is an emerging research area with a longer lead time for implementation. Activities in the area of mobile observations are still in foundational stages and currently, State and local agencies continue to view this as a long-term goal. From a performance measurement standpoint, it is premature to look at end-user outcomes of these efforts just yet.

Table 2-3. Linking 2009 and 2012 RWMP Objectives

Objectives in 2009	Objectives in 2012
Develop a national, open observing system that promotes data sharing to support weather observing and forecasting and transportation operations.	
	Advance the Collection, Processing, and Distribution of Fixed and Mobile Observations.
	Improve Overall System Performance During Weather Events.
Develop resources and training methods to assist State and local partners in deployment of weather management tools.	Raise Road Weather Management Capabilities and Knowledge across the Transportation Industry.
Advance the State-of-the-practice by developing proactive solutions and disseminating information on adverse weather.	Develop and Support Operational Deployment of Advanced Road Weather Management Strategies.
	Increase the Use of Weather-Based Decision Support Tools and Dynamic Mobility Applications.
Foster a collaborative, comprehensive, and dedicated surface transportation weather research program.	Build Partnerships with Transportation and Weather Communities.
	Engage the Climate Change Community in Transportation Maintenance and Operations.

Source: Battelle

Recent activities of the RWMP have focused on the revised 2012 objectives. Table 2-4 below provides an overview of the RWMP activities used to track RWMP performance associated with each revised objective. Chapter 4 provides more details on the activities listed in the second column of this table.

Table 2-4. RWMP Initiatives under the MAP-21 and FHWA Driven Objectives

Objective	Major Activities/Initiatives/Accomplishments
1. Build Partnerships with Transportation and Weather Communities	• RWMP Stakeholder Meetings. • Participation with Cooperative Research Programs including PFS. • Partnership activities with the transportation and weather community (TRB, AASHTO, Aurora, Clear Roads, National Committee of the USA World Road Association (PIARC), NOAA/National Weather Service (NWS) AMS etc.).
2. Raise Road Weather Management Capabilities and Knowledge across the Transportation Industry	• Webinars. • Online training courses. • New road weather tools. • WRMP strategies, demonstrations, and evaluation guidelines.
3. Advance the Collection, Processing, and Distribution of Fixed and Mobile Observations	• Vehicle Data Translator Research. • Integrated Mobile Observations Project. • Data Capture and Management Activities (i.e. Weather Data Environment). • Use of Mobile Data for WRTM. • *Clarus* Broad Agency Announcement (BAA) and Multi-State Demonstration program.
4. Increase the Use of Weather-Based Decision Support Tools and Dynamic Mobility Applications	• Traffic Analysis Tools and Models. • Weather sensitive TrEPs implementation. • MDSS deployment tracking and monitoring. • Dynamic Mobility Applications. • Development and use of *Clarus* BAA and Multi-State Demonstration program tools.
5. Develop and Support Operational Deployment of Advanced Road Weather Management Strategies	• Implementation and evaluation of WRTM Strategies. • Development of Guidelines for road weather management messages and variable speed limit (VSL) systems. • Support for TMC Weather Integration. • Development and use of *Clarus* BAA and Multi-State Demonstration program tools for travel advisories.
6. Improve Overall System Performance During Weather Events	• Adoption of RWMP supported best practices. • Cost-benefit analysis of road weather management strategies. • Evaluations of system performance.
7. Engage the Climate Change Community in Transportation Maintenance and Operations	• Defining the Operations & Maintenance measures pertaining to road weather in FHWA-developed checklist for sustainability called INVEST. • Promote the concepts of sustainability within the maintenance community. • Work with the climate community to better understand the potential impacts of climate change on Operations & Maintenance, to determine knowledge gaps, to identify R&D needs, and to explore how climate change could be incorporated into O&M practices. • Support a national, multi-disciplinary effort led by OSTP & NOAA to determine weather observing needs for the transportation community.

Source: Battelle

Identifying and Filling Gaps in 2009 Measures

To track longitudinal progress, the process of updating the performance measurement conducted in 2009 should seek to use the same measures that were considered good determinants of performance. However, as the activities in the sections above indicate, the last few years have been a period of transition for the program. While the program continues to accelerate the deployment and use of market-ready products like MDSS, it has also embarked on foundational research, especially in the area of Connected Vehicles. In addition, it is important to explore performance-related activities that have occurred outside but also pertains to the RWMP, such as reliability measures, MAP-21 performance requirements, FHWA's OEI, SAFETEA-LU's Section 1201 Rule, and State-level performance measurement activities. The update also provides the opportunity to identify measures which were not easily quantified due to data limitations and identify an approach for assessing those measures. Table 2-5 provides a summary of measures that still exist today, their strengths and weaknesses in relation to the 2012 objectives and the challenges involved in tracking them.

Table 2-5. Linking 2009 Performance Measures to 2012 Objectives

2012 Objectives	Applicable Performance Measures and Indicators from 2009 Performance Measurement	Strength and Weaknesses of the Current Indicators/Performance Measures	Challenges to Track Performance for the 2012 Objective
Stakeholder Coordination & Technical Transfer, Training and Education Focus Areas			
Build Partnerships with Transportation and Weather Communities	1. Number of agencies participating in and benefiting from road weather R&D projects. 2. Number of Transportation Agencies Participating in *Clarus* Initiative Activities. 3. Number of agencies participating in *Clarus*/MDSS stakeholder meetings. 4. Number of road weather technology development projects initiated by public, academic, or private sector agencies based on RWMP or State transportation agency input. 5. Number of RWMP influenced-or involved Road Weather Technologies developed through public-private and/or public-public partnerships reaching operational deployment.	The indicators are good demonstrations of the partnership and collaborative nature of the program. Gaps are primarily in the quantification of the measures and inclusion of the various partners. For example, groups not included in the previous assessment include TMC PFS, corridor coalitions, etc. There are also no indicators for internal partnerships within the DOT. This area also needs to include the coordination with NWS/NOAA especially as it relates to transitioning *Clarus to* MADIS.	The primary challenge is to capture the products of the partnership and collaboration efforts beyond meetings, and research reports.
Raise road weather management knowledge and capabilities across the transportation industry	1. Number of agencies/ individuals visited or contacted through tech transfer, training and outreach efforts (i.e. webinars, workshops, etc.). 2. Number of training activities delivered by RWMP (e.g. Consortium for ITS Training and Education [CITE] Courses).	Still relevant to 2012 objectives. However, these measures mostly track participation and engagement rather than comprehension.	The broad nature of the objective and the overlap with other objectives makes it difficult to isolate performance. (May need to separate out the various tech transfer, training and outreach efforts).

Table 2-5. Linking 2009 Performance Measures to 2012 Objectives (Continued)

2012 Objectives	Applicable Performance Measures and Indicators from 2009 Performance Measurement	Strength and Weaknesses of the Current Indicators/Performance Measures	Challenges to Track Performance for the 2012 Objective
Road Weather Management Research & Development Focus Areas			
Advance the collection, processing and distribution of fixed and mobile road weather observations	1. Number of Transportation Agencies contributing ESS data to *Clarus* System. 2. Number of transportation agencies that subscribe to road weather products and services. 3. Number of transportation agencies providing fixed and mobile data via the web or other dissemination methods (may have to separate fixed and mobile observations).	The indicators for this objective need to demonstrate progress towards both increased use of fixed observations and Increased use of mobile observations. The current indicators do not include mobile data collection. They also do not provide any indication of the quality of weather data. Due to early stages of research and operations, the use of mobile observations by agencies is expected to be limited. Current indicators also do not track the distribution of fixed and mobile sensors.	With the *Clarus* System transitioning to Meteorological Assimilation Data Ingest System (MADIS), the relevance of the *Clarus* System related indicators is reduced or unclear.
Increase the use of weather-enabled advanced decision-support tools and dynamic mobility applications	1. Number or percentage of transportation agencies that use road weather info and decision support systems for making advisory, control and treatment decisions. 2. Number of agencies adopting MDSS technologies and methods.	The MDSS indicator is important to track however as a measure of performance. Decision-support in 2010 was focused primarily on MDSS. The performance indicators now need to include the tools emerging out of the *Clarus* multi-State demonstration, TrEPS and others. It is important to define what is meant by decision-support in this broader context.	Other than MDSS, other tools are still in their infancy operationally. Also, with MDSS maturing, the nature of use of MDSS needs to be captured distinguishing between the power-users of MDSS and those that just use MDSS as a strategic weather service.
Develop and support operational deployment of advanced road weather management strategies	1. Number of States disseminating weather and road weather information to travelers.	The indicators are useful but not sufficient. The use and adoption of other WRTM strategies is missing.	No significant challenges identified.

Table 2-5. Linking 2009 Performance Measures to 2012 Objectives (Continued)

2012 Objectives	Applicable Performance Measures and Indicators from 2009 Performance Measurement	Strength and Weaknesses of the Current Indicators/Performance Measures	Challenges to Track Performance for the 2012 Objective
Program and Performance Measurement Focus Area			
Improve overall system performance during weather events	1. Reduction in agency costs of winter maintenance activities. 2. Reduction in number and types of fatalities and crashes attributed to adverse weather nationally. 3. Reduction in the extent of capacity losses and delays due to fog, snow, and ice events.	These indicators are well suited for the 2012 objective which is focused on the ultimate end-user outcomes. No significant gaps in terms of performance except in the area of travel reliability.	The primary challenge is to associate the end-user outcomes with RWMP products, activities and services especially for projects in foundational stages. The lack of comprehensive and analytically consistent evaluation studies continues to be a challenge.
Operations and Climate Change Focus			
Engage the climate change community in transportation maintenance and operations	1. This was not a 2010 objective; hence, no measures were identified.	This is an emerging research area with limited products/activities/services provided by the RWMP. Early efforts have included participation in DOT/FHWA sustainability activities including supporting the development of the INVEST Tool.	It is still unclear what activities will be conducted to support this objective. It may be premature to measure performance.

Source: Battelle

Chapter 3 Updated Performance Measures

Building on the discussion in Chapter 2, this chapter lists the updated performance measures that are used to assess program performance in 2012.

Approach to Updating Performance Measures

The first step in the update process was to understand the various activities that have been conducted since 2009, their impact on the existing performance measures, and the challenges associated with performance measurement for these new activities. Some of these activities are new and others are a continuation of previous activities (with or without modifications). The result of this step was the development of a technical memorandum that summarized the evolution of the program since the previous performance measurement report was published. Next, a literature review was conducted to identify new and emerging performance measures. The review focused on the reliability research conducted through the SHRP2, MAP-21 performance requirements, FHWA's OEI, SAFETEA-LU's Section 1201 Rule, and State-level performance measurement activities. The result of this step was documentation of new measures external to the program that impact road weather management performance. At the conclusion of these steps, a suggested list of measures was drafted and presented to FHWA for approval. One of the main challenges was to ensure consistency and simplicity while adapting to the new directions of the program. These measures were vetted and approved by the RWMP.

Updated Performance Measures for 2012

As discussed above, the final list of performance measures for 2012 was updated based on an internal review of RWMP activities as well as examining external needs and performance-related initiatives that affect the program. Table 3-1 is organized by the seven program objectives and contains measures that remain unchanged from 2009, measures modified from those used in 2009, and several new measures reflecting current RWMP priorities. The resulting twenty two (22) measures characterize the performance of the program across the seven objectives. More details on the definition of the measures are provided as part of the discussion of the results in Chapter 4.

Table 3-1. RWMP Performance Measures for 2012

RWMP Objectives	Final 2012 Performance Measures
Build partnerships with transportation and weather communities	1. Number of agencies participating in road weather R&D projects. 2. Number of agencies participating in and benefiting from Road Weather Management stakeholder meetings/workshops. 3. Number of organizations/groups where FHWA is represented (National and International).
Raise road weather management knowledge and capabilities across the transportation industry	4. Number of agencies and attendees who have taken any of the training courses sponsored by the RWMP. 5. Number of agencies and participants in road weather management webinars. 6. Number of meetings, site visits or venues where road weather management presentations/briefings were made. 7. Number of hits/visits to RWMP websites.
Advance the collection, processing & distribution of fixed and mobile road weather observations	8. Number of transportation agencies participating in road weather data sharing activities. 9. Number of transportation agencies that subscribe to road weather products and services. 10. Number of agencies collecting mobile observations of road weather data from vehicle fleets. 11. Number and distribution of fixed Environmental Sensor Stations (ESS).
Increase the use of weather-enabled decision-support tools and dynamic mobility applications	12. Number of agencies adopting MDSS technologies and methods. 13. Number of agencies using other weather-related decision-support tools. 14. Number of agencies using weather-responsive traffic-related analysis, modeling, simulation and decision-support tools.
Develop and support operational deployment of advanced road weather management strategies	15. Number of States disseminating advisory weather and road weather information to travelers. 16. Number of agencies using control and treatment strategies during weather events.
Improve overall system performance during weather events	17. Reductions in agency costs of weather-related maintenance and operations activities. 18. Reduction in number and types of fatalities and crashes attributed to adverse weather nationally. 19. Reduction in the extent of capacity losses and delays due to fog, snow, and ice events including freight. 20. Increase in travel time reliability or decrease in variability due to road weather management strategies during adverse weather scenarios. 21. Reduction in number of tons of salt or chemical usage in the U.S. normalized by winter severity index.
Engage the climate change community in maintenance and operations	22. Number of public agencies meeting "INVEST" and/or sustainability criteria related to road weather management.

Source: Battelle

Operationalizing the Measures

Operationalizing these measures and more importantly attributing the impact of the RWMP is the focus of Chapter 4. This section identifies assumptions, constraints and data sources used to quantify the twenty-two (22) measures in Table 3-1.

Data Sources

Data for operationalizing the measures included the following four sources:

1. **RWMP Records** – One of the main sources of information, especially for measures relating to stakeholder engagement, training and partnership building were the records kept by RWMP staff over the years. The data included items such as number of participants in training events and attendance lists at stakeholder meeting. The RWMP was also the source for data on the *Clarus* and MDSS initiatives. These data sources were compiled to identify the breadth and depth of RWMP partnerships across the nation.
2. **State DOT Surveys** – For identifying current levels of deployment and capabilities relating to road weather management, a targeted survey was distributed to forty-eight (48) State DOT representatives. Thirty (30) responses were received from twenty-seven (27) States for a response rate of 56.5 percent. Crucially, as Figure 3-1 illustrates, the respondents comprised almost all the winter-weather State DOTs. Appendix A includes the survey instrument and the frequency distributions of the collected responses.

Source: Battelle

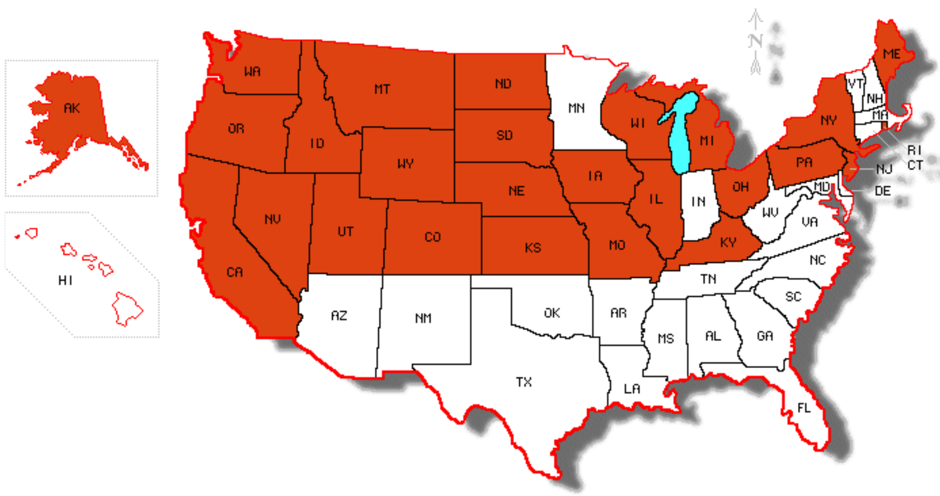


Figure 3-1. Map of 2013 Survey Respondents

3. **Other Survey Sources** – The ITS Deployment Statistics[8], ITS Benefit-Cost Database[9], and the FHWA OEI were three other survey-based sources used in the quantification of measures. The ITS Deployment Statistics was used extensively in the previous performance measurement as the survey contained direct questions relating to road weather in 2004 and 2007. However, changes in the deployment tracking survey for 2012 resulted in road weather questions being either eliminated or subsumed into larger questions, thereby preventing longitudinal comparisons. The ITS Benefit-Cost database continued to be used as a source for case studies and evaluation results relating to safety, mobility, productivity and customer satisfaction. The OEI is reported internally by FHWA Division Offices. Due to restrictions on its use, detailed OEI information is not presented in this report.
4. **Literature Reviews –** Since the previous performance measurement activity, there has been a profusion of road weather information in the community driven by Pooled Fund Studies (PFS) such as AURORA, Clear Roads, Enterprise, and Traffic Management Center (TMC) Pooled Fund. Several of these pooled fund activities have supported benchmarking and evaluation activities for their members. These have been compiled as part of this study. In addition, Transportation Research Board (TRB) committee activities have also resulted in research papers especially to support safety and reliability modeling for road weather. These studies were also reviewed for their potential use in quantifying the measures.

Assumptions and Constraints

The following are the assumptions and constraints that should be kept in mind while reviewing the results presented in Chapter 4:

- For measures pertaining to the quantification of the involvement of agencies in road weather management product, services and activities development or deployment, the data do not support the level of involvement of local government or other international entities. State DOTs are used as the primary unit of measurement, as they represent the primary stakeholders for RWMP. However, the involvement of other agencies is highlighted and quantified where possible.
- For measures relating to safety, mobility and productivity (measures #17-21 in the table), several case studies and evaluation results are presented in lieu of a single measure. This is primarily because variations in national level statistics are difficult to attribute specifically to RWMP activities.
- Longitudinal comparisons between measures reported in 2009 and 2012 are reported where possible. However, due to significant changes in measure definition, and as reported in one of the core data sets (ITS Deployment Statistics), the power and the efficacy of the longitudinal comparison is limited.
- For measures relating to partnerships, training and stakeholder outreach, the measures were operationalized to the extent that RWMP records allow.

[8] RITA, ITS Deployment Tracking Database, available at www.itsdeployment.its.dot.gov.

[9] RITA, ITS Benefits and Costs Database, available at www.itsbenefits.its.dot.gov.

Challenges

The following are the challenges encountered in quantifying the measures described in Chapter 4:

- Normalizing measures across the nation, especially the mobility, productivity and safety outcomes continues to be a challenge. The lack of a widely accepted approach for calculating winter severity for the season makes temporal comparisons difficult.
- While measures relating to reliability and sustainability were quantified to the extent data allowed, these measures are still in a formative stage. As new data and approaches emerge from SHRP2 (in the case of reliability) and the community (in case of climate change and sustainability), these measures can be quantified more robustly.
- Where possible, best practices supported by the RWMP were used to illustrate the potential benefit of the measure. It is clearly recognized that RWMP, while playing an important leadership role, is not the only proponent of these strategies. The important role played by the various PFS, American Association of State Highway and Transportation Officials (AASHTO), and the State DOTs themselves in developing and adopting strategies to better manage their roadways during weather cannot be understated or minimized as a pathway to benefits.

This page intentionally left blank.

Chapter 4 RWMP Performance and Results

This chapter presents the performance of the RWMP as defined by the twenty-two measures identified in Table 3-1. In order to explicitly link the activities undertaken by the program to the measures, this chapter is organized by RWMP objectives

Objective 1: Build Partnerships with Transportation and Weather Communities

The RWMP has maintained a core emphasis on fostering a collaborative, comprehensive, and dedicated surface transportation weather research program. The RWMP has reached out to a variety of stakeholder groups to participate in collaborative research and development (R&D) activities and emphasized strengthening existing partnerships and seeking new partnerships.

Historically the program has focused heavily on issues associated with winter road maintenance and the use of new tools, such as the MDSS, to achieve cost-effective strategies for enhancing mobility and safety during adverse weather. Since its inception, the RWMP has built partnerships with the National Oceanic and Atmospheric Administration (NOAA), National Center for Atmospheric Research (NCAR), Office of the Federal Coordinator for Meteorology (OFCM), Snow and Ice Pooled Fund Cooperative Program (SICOP), AASHTO Subcommittee on Maintenance (SCOM), National Committee of the USA World Road Association (PIARC), Clear Roads, Aurora Pooled Fund Program, American Meteorological Society (AMS), National Weather Service (NWS), American Association of State Highway and Transportation Officials (AASHTO), TRB, ITS America, and other groups in the transportation and weather communities.

Since 2010, the RWMP has continued to support symposia and partnership-building and recently has expanded the coverage to emerging topics of interest, such as social media, WRTM and connected vehicle technologies. Participation now includes a broader mix of stakeholders, and progress has been achieved in terms of increased attention to weather in national forums such as TRB and pooled fund activities. Key partnerships are leading to important tangible accomplishments, such as the transition from *Clarus* to Meteorological Assimilation Data Ingest System (MADIS).[10] Performance measurement for this program objective primarily focuses on output measures, such as the extent of partnerships established, growth in stakeholder participation, and increased recognition and acceptance by the stakeholders of the leadership role played by the program.

[10] On June 30, 2013 *Clarus* was shut-off in preparation for MADIS transition.

PM-1. Number of Agencies Participating in Road Weather R&D Projects

This measure illustrates the extent to which State and local DOTs and agencies are participating in the R&D projects initiated by the RWMP. These R&D activities cover all the major initiatives of the RWMP including *Clarus,* MDSS, WRTM, and Connected Vehicle research.

This measure shows the engagement and partnership with the State DOTs and others in implementing the RWMP's research agenda for road weather management. The continued involvement of agencies is a direct testament to their perceived benefit of the RWMP R&D efforts. The breadth of involvement also indicates the reach and collaborative nature of the R&D efforts.

The data for this measure are gathered from interviews with RWMP personnel and review of the R&D program. The RWMP has encouraged State transportation agency participation in demonstrations and pilot projects for a number of innovative road weather research areas. Some of these include WRTM studies, road weather information system research involving the NWS and universities, the *Clarus* Initiative including the development of a multi-State regional demonstration and an ESS Connection Incentive program, the deployment of MDSS in several States, the evaluation of Road Weather Information Systems (RWIS) siting guidelines, and the integration of road weather information within traffic management operations. Each of these has included agency participation during various aspects of the R&D project activities. For the demonstrations involving agency participation there is a direct benefit gained through agency personnel involvement.

Table 4-1 lists the agencies that have participated in a significant manner in the recent R&D efforts of the program, including situations where the agency was a grant recipient of the RWMP. In many of the cases listed, these agencies contribute matching funds or resources (in terms of staff time at a minimum) to participate in these projects.

Table 4-1. List of Public Agencies Participating in Road Weather Management Program R&D Activities (2000 – 2012)

Research Activity	Public Agencies Directly Involved in RWMP R&D
***Clarus* System**	39 States, five local agencies, four Canadian provinces, NOAA, and NWS
***Clarus* Multi-State Demonstrations**	Idaho Transportation Department, Illinois DOT, Indiana DOT, Iowa DOT, Minnesota DOT, Montana DOT, North Dakota DOT, South Dakota DOT
***Clarus* BAAs**	California DOT, Idaho Transportation Department, Nevada DOT, New York DOT, North Dakota DOT, Oregon DOT, Washington DOT
Weather Responsive Traffic Management*	California DOT, Colorado DOT, Louisiana DOT, Maryland SHA, Missouri DOT, New York DOT, Oregon DOT, Utah DOT, Washington DOT, Wyoming DOT, City of Colorado Springs, Chicago, Irvine, Environment Canada
Integrated Mobile Observations/CV	Michigan DOT, Minnesota DOT, Nevada DOT
MDSS	Colorado DOT, Iowa DOT, Maine DOT, City and County of Denver, National Center for Atmospheric Research
Western States Rural Transportation Consortium	California DOT, Nevada DOT, Oregon DOT, Washington DOT

*WRTM R&D includes TMC weather integration, Human Factors, TrEPs, and WRTM implementation.

Source: Battelle

Figure 4-1 below illustrates the breadth of involvement in RWMP research in terms of the number of RWMP activities in which a State agency has been involved, by State in 2012. Note that local, Federal agency and international involvement are not shown in Figure 4-1. Thus, for example, California DOT is involved in seven different RWMP activities and Maine DOT was involved in two.

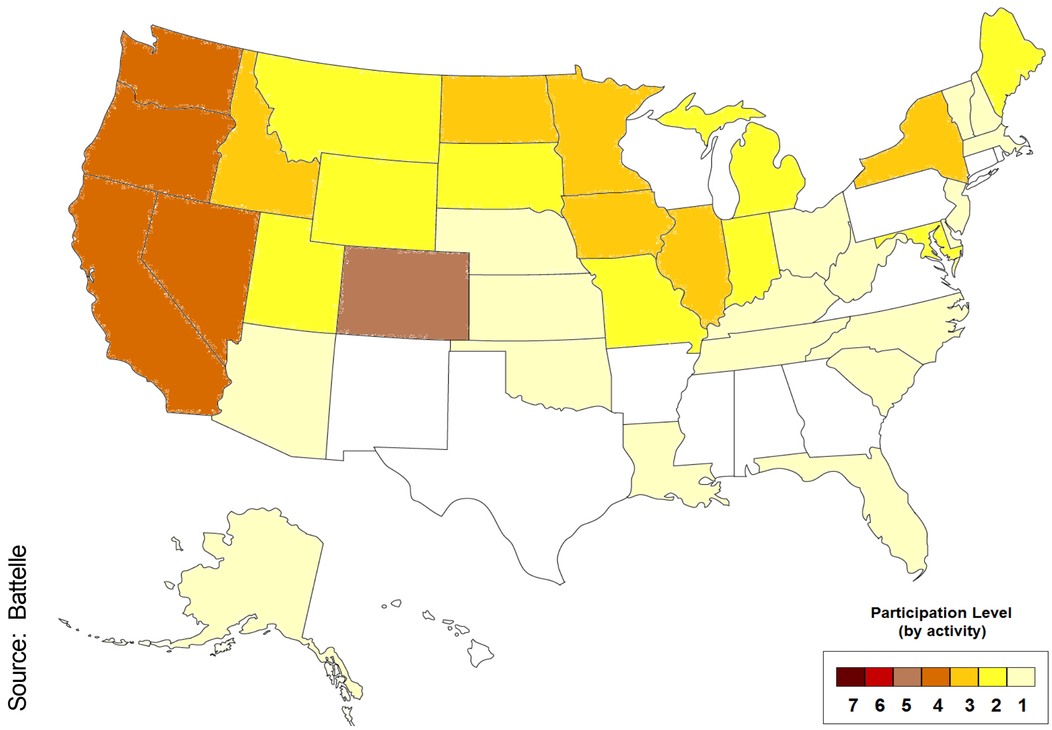


Figure 4-1. Map of United States Illustrating Breadth of Agency Involvement, by State, in RWMP Activities (2012)

PM-2. Number of Agencies Participating in and Benefiting from Road Weather Management Stakeholder Meetings/Workshops

The RWMP stakeholder meetings have been conducted since 2000. Initially focused on MDSS, then on *Clarus*/MDSS[11], now broadly on road weather management, this measure tracks State participation in these meetings. In addition to the RWMP stakeholder forum, a subset of stakeholders was also convened for WRTM starting in 2011. This measure is important to gauge the continued interest and growth of the RWMP stakeholder community. While evaluations from the meeting show very positive feedback from the attendees, this measure as quantified assumes that continued participation is an implicit acknowledgement of the perceived benefits by the attendees. The data for this measure are from statistics maintained by the RWMP.

[11] During this time, the *Clarus* and MDSS meetings were held back to back in the same location. Different but overlapping sets of stakeholders participated in each of these meetings.

Figure 4-2 illustrates the attendance by year by the State DOTs in the stakeholder meetings. In addition to State DOTs, various other private and public agencies attend the stakeholder meeting. These agencies are not included in the measure since detailed participation records for the early MDSS/*Clarus* meetings are not available. From 2001 to 2003, the focus of the stakeholder meetings was on MDSS. From 2004-2009, both *Clarus* and MDSS were discussed in the stakeholder meetings. From 2010, the stakeholder meeting focused on broader RWMP activities.

Source: RWMP Data

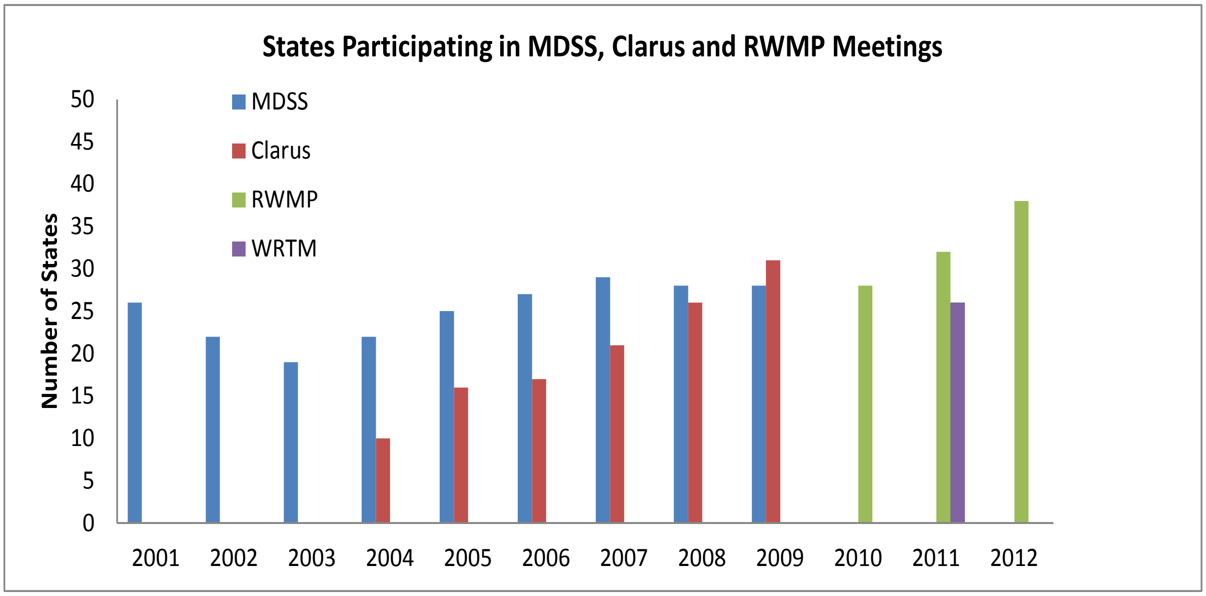


Figure 4-2. Yearly Levels of State Participation in Stakeholder Meetings

PM-3. Number of Organizations/Groups where FHWA is Represented (National and International)

This measure tracks RWMP participation and leadership in the broader road weather community. By advising, participating in and managing various forums, the RWMP broadens the nature of partnerships and capacity of the road weather community. This measure directly addresses partnership building, the core of this objective. As FHWA's role and participation in these external forums grow, their ability to influence, support and champion road weather management increases. The data for this measure are gathered from interviews with RWMP personnel. Creating the list of organizations/groups in which RWMP is represented was the first step in operationalizing this measure. However, the RWMP does not play the same role in all these organizations. In some groups, the RWMP has an official role and in other cases, it is a member. Official roles allow RWMP to be in a leadership role setting the agenda and strategic direction of the organization/group. Table 4-2 identifies a list of organizations/groups where the RWMP is represented and the nature of their role in those organizations.

Table 4-2. Organizations/Groups and Role of FHWA RWMP

Organization	RWMP Self-Assessment of Role	
	Officer	Member
Aurora		X
Clear Roads		X
Traffic Management Center (TMC) Pooled Fund Study		X
AASHTO Subcommittee on Maintenance		X
AASHTO Winter Maintenance Technical Services Program/ Snow and Ice Pooled Fund Cooperative Program (SICOP)	X	
Transportation Research Board (TRB) Weather Committee	X	
TRB Winter Maintenance	X	
World Road Association – PIARC	X	
Office of the Federal Coordinator for Meteorological Services		X
American Meteorological Society		X
ITS America		X
Institution of Transportation Engineers		X
American Public Works Association		X

Source: FHWA

Summary of Performance across the Objective

Overall, the three performance measures reveal strong engagement, with partnerships fostered and supported by the RWMP. The first performance measure illustrates the depth and breadth of State DOT engagement across all of the program's major initiatives. The *Clarus* program, itself has involved thirty-nine States in multiple roles. Most of them have been as a data provider but other States have participated in advanced applications of *Clarus* data. While the *Clarus* System will cease to function at the end of 2013, the RWMP is working with connected States to transition to the NOAA-hosted MADIS system as well as creating a research-oriented weather data exchange portal.

The stakeholder meetings continue to be a valuable forum for information exchange in the road weather management community evolving over time from *Clarus* and MDSS focused meetings to take on a broader road weather management agenda.

The breadth and the leadership role of the RWMP continued to grow across the various organizations/groups listed in Table 4-2. As the other measures will illustrate, the RWMP bridges the ITS, traffic management, meteorology, roadway maintenance, planning, and sustainability communities both nationally and internationally.

Objective 2: Raise Road Weather Management Knowledge and Capabilities across the Transportation Industry

Providing training, education, technical assistance, technology transfer, and resources to assist States and partner transportation agencies in more fully taking weather into account in their management and operational responsibilities has been an important component of the RWMP since its inception. Since 2000, the RWMP has produced and made available through their website various outreach documents, technical reports and papers. In 2012 this objective has been broadened to focus on expanding and strengthening the range of road weather capabilities throughout the transportation industry. Examples of recent capacity building efforts include:

- Published an electronic version of the MDSS Deployment Guide.
- Demonstrated four *Clarus* Use-Cases and an independent evaluation of each, providing guidance to State DOTs in advanced road weather applications.
- Published revised ESS Siting Guidelines.
- Developed road weather tools, such as the Road Weather Resource Identification (RWRI) Tool, accessible through the RWMP website.
- Developed and refined road weather messaging guidelines that can be used by DOTs and agencies in more effectively communicating road weather information to the traveling public.
- Published an update on road weather as part of the Traffic Analysis Toolbox.
- Completed a study entitled "Incorporating Weather Impacts in Traffic Estimation and Prediction Systems (TrEPS)."
- Published an online study of "Microscopic Analysis of Traffic in Inclement Weather."
- Completed a study entitled "Developments in Weather Responsive Traffic Management."
- Developed and made available online "TMC Weather Integration Self-Evaluation and Planning Guidelines."
- Completed a study of "Developments in Weather Responsive Traffic Management Strategies," and following this with the demonstration and evaluation of selected strategies by State DOTs as a demonstration of advanced road weather concepts of operations.
- Developed an online course on Weather Responsive Traffic Management.
- Developed an online course on an introduction to RWIS equipment and operations.
- Developed classroom and web-based versions of "Principles and Tools for Road Weather Management."
- Presented a series of webinars on current topics in road weather management, including the uses of social media in more effectively communicating with the public.

PM-4. Number of Agencies and Attendees who have taken any of the Training Courses Sponsored by the RWMP

The RWMP has provided several training courses related to road weather management as well as the MDSS Road Show. This measure tracks the participation of agencies and attendees in these programs. Training is one of the key approaches to increasing the knowledge and capabilities of the transportation community and promoting advanced road weather management strategies. Tracking this measure indirectly documents the relevance and usefulness of the training provided by the RWMP to the practitioners.

This measure was quantified in the previous performance update. Since then, in order to reach a larger audience, the information for some of the online training courses has been more widely publicized. Participation by sessions and attendance for the various training programs since 2009 is shown in Table 4-3.

Partnering with other transportation and weather agencies also helps RWMP training courses to gain valuable exposure during the development and implementation of these training activities. The National Highway Institute offers a one day, on-site course on basic technologies and strategies for addressing road weather problems. Road weather management solutions cover all aspects of highway management practices, including operations, maintenance, traffic, emergency and safety management. This course is now available through a web-based version developed by the RWMP and the Consortium for ITS Training and Education (CITE). Since its implementation in 2005, the course has had a steady number of participants for each of four training sessions. The blended course has also been delivered four times with an increase in participants for the last training session in the fall of 2012.

Table 4-3. Number of Agencies and Attendees Participating in Road Weather Management Program Training Activities Since 2009

Training Activities and Sponsorship	Number of Participants (self-study and blended)	Details of Session
Principles and Tools for Road Weather Management	59	Blended
	19	Self -study
Weather Responsive Traffic Management	36	Fall 2012
	19	Summer 2013
	17	Self-study
Road Weather Information Systems (RWIS) Equipment and Operations (CITE Maryland)	62	Blended
	28	Self-study

Source: University of Maryland - CATT Lab

CITE also offers two other RWMP courses in both instructor-led, web-based (“blended”) courses and online, independent study courses. The WRTM course provides participants with an understanding of the strategies, data types, analysis tools and performance monitoring necessary to effectively manage traffic during weather events. This course was offered in fall 2012 and summer 2013 as well as through self-study. The course titled “Road Weather Information Systems (RWIS) Equipment and Operations” focuses on the value of RWIS and the benefits of RWIS to a particular region. The course provides participants with an action plan tailored for their specific regional needs. Since the fall of 2010, this course has been offered three times and has had consistent participation numbers.

CITE now offers a certificate course in Road Weather Management to participants who have taken all three courses listed above plus an additional ITS-related course. This certificate program began in 2013 and the number of participants attaining the certificate needs to be tracked in future years.

A module titled "Fundamentals of Road Weather Management" was developed by the FHWA in partnership with the Institute of Transportation Engineers (ITE) that provides general road weather management information, including problems, management strategies, available technologies and best practices. A one hour training CD is available through the ITE Bookstore. The module was first made available in the fall of 2008 and has been marketed successfully to 40 participants.

In addition to these courses, the FHWA has offered the MDSS Roadshow, a free seminar describing the capabilities of a MDSS to those involved with winter road operations. The Roadshow is separated into two versions. The Roadshow Executive Briefing focuses on prospective cost savings and how managers can effectively deploy MDSS technologies and resources. The thirty minute briefing is geared towards transportation agency executives. The MDSS Shop Session is a three hour session that highlights key elements of MDSS, including the use of real-time winter weather information, numerous winter maintenance treatment options, and how MDSS can be used as a training tool. Although the format has changed since 2008 to have a more regional focus, the Roadshow was conducted across the country 28 times between 2006 and 2008 and hosted a total of 925 participants. There have been no new deliveries of the Roadshow, indicative more of the general level of comfort with MDSS in the community rather than lack of interest.

PM-5. Number of Agencies and Participants in Road Weather Management Webinars

The RWMP has increasingly used webinars as an outreach mechanism to promote research results and publicize the availability of guidance documents. Conducted mainly through the National Transportation Operations Coalition (NTOC) as part of the "Talking Operations" series, the RWMP webinars are well-attended by a diverse group of stakeholders. This measure tracks the number of individuals participating in these webinars. Participation in the webinars reflects the level of interest and engagement in RWMP research products and services. By tracking the continued participation and affiliation of the participants, the relevance of RWMP products and services can be indirectly assessed.

All RWMP webinars are free of charge. Each webinar is recorded and archived on the NTOC site including closed captioning, a webinar transcript, a chat transcript and links to the associated presentations. The ability to host and share webinars in this manner allows for higher participation rates and a more thorough dissemination of information.

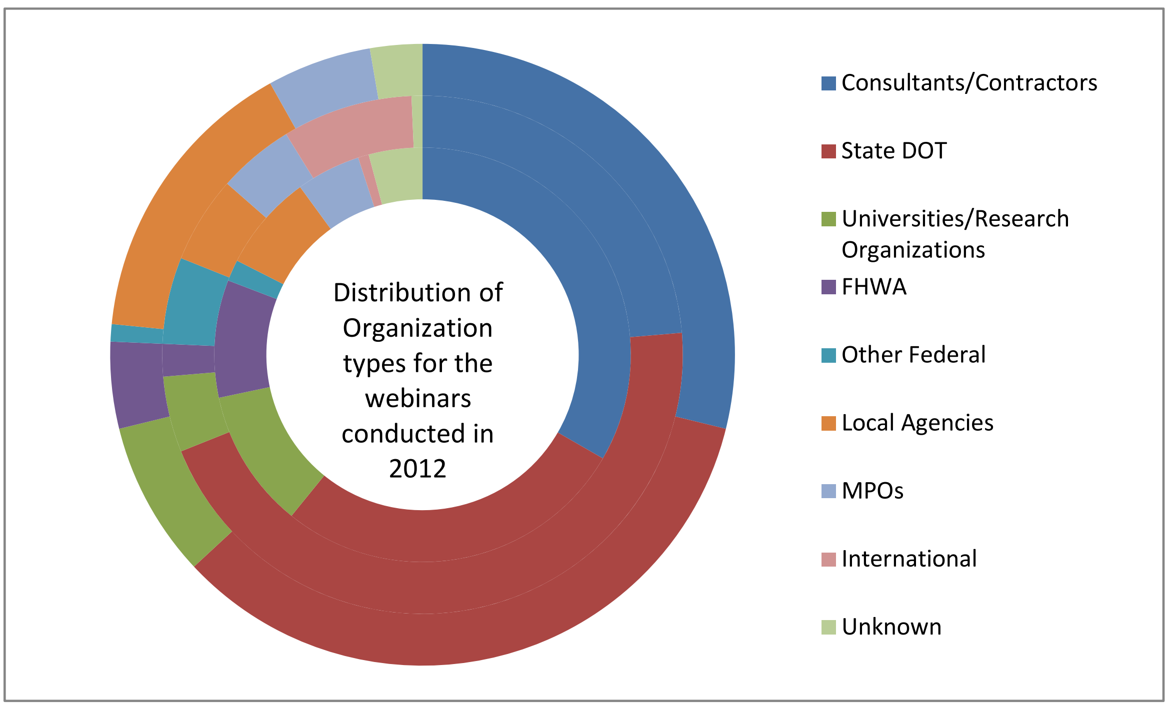
The data for implementing this measure were made available through the archive maintained by NTOC. Table 4-4 provides a list of webinars offered by the RWMP through NTOC along with corresponding dates and number of participants.

Table 4-4. Participation in NTOC-hosted RWMP Webinars Since 2006

Webinar	Date	Participants
WRTM – Guidelines for Disseminating Road Weather Advisory & Control Information	November 1, 2012	99
WRTM – Weather Responsive Traffic Signal Management	May 31, 2012	111
WRTM – Use of Social Media During Weather Events	April 19, 2012	148
WRTM – Active Traffic Management (ATM) and Weather	March 20, 2012	121
Integrating Weather Information in TMC Operations	August 6, 2009	98
Road Weather Management Update	September 30, 2008	75
Road Weather Management Update	March 14, 2007	160
Road Weather Management Update	January 11, 2006	210

Source: RWMP Data

Since the first RWMP webinar in 2006, the program has experienced consistently high, increasing participation levels. Four webinars were hosted between 2006 and 2009 with a total of 543 participants. In 2012 alone, four RWMP webinars were held with a total of 479 participants. This increase in annual participation shows a high level of interest in the webinars even after a two year lull. The diversity of webinar attendees is illustrated in Figure 4-3, showing the webinar attendees include Federal, State, local and private sector stakeholders.



Source: NTOC

Figure 4-3. Distribution of Attendees by Organization Type for Three Webinars Hosted 2012

PM-6. Number of Meetings, Site Visits or Venues where Road Weather Management Presentations/Briefings were made

This measure tracks the broad nature of engagement of the RWMP. Other than the focused training activities and webinars, the RWMP also provides a wide variety of presentations and briefings at various meetings, site visits or venues as well as technical documentation on their website. RWMP staff and contractors continued to present at various professional associations to the road weather community. Excluding presentations made at RWMP-sponsored events, during 2009 to 2012, the RWMP has presented in every TRB Annual Meeting, AMS Annual Meetings, TRB-sponsored International Conference on Winter Maintenance and Surface Transportation Weather, Aurora, Clear Roads, ITS-Irvine, Connected Vehicle Pool Fund Study, ITS America 2012, and PIARC – Winter Maintenance Technical Committee. Exact numbers of attendees at each presentation are difficult to obtain given the diversity of engagements to which RWMP is invited to participate.

PM-7. Number of Hits/Visits to RWMP Websites

The RWMP website[12] is the main source of dissemination of information for the program. In addition to the RWMP website, road weather information is also available on the partner Intelligent Transportation Systems Joint Program Office (ITS-JPO) website[13]. Other RWMP websites include the website hosting the *Clarus* System[14]. In 2012, sixty-eight (68) percent of the respondents to the evaluation survey conducted after the annual stakeholder meeting had visited the RWMP website. Of these respondents, 71 percent had downloaded materials. These indicate a high degree of use and awareness of the website.

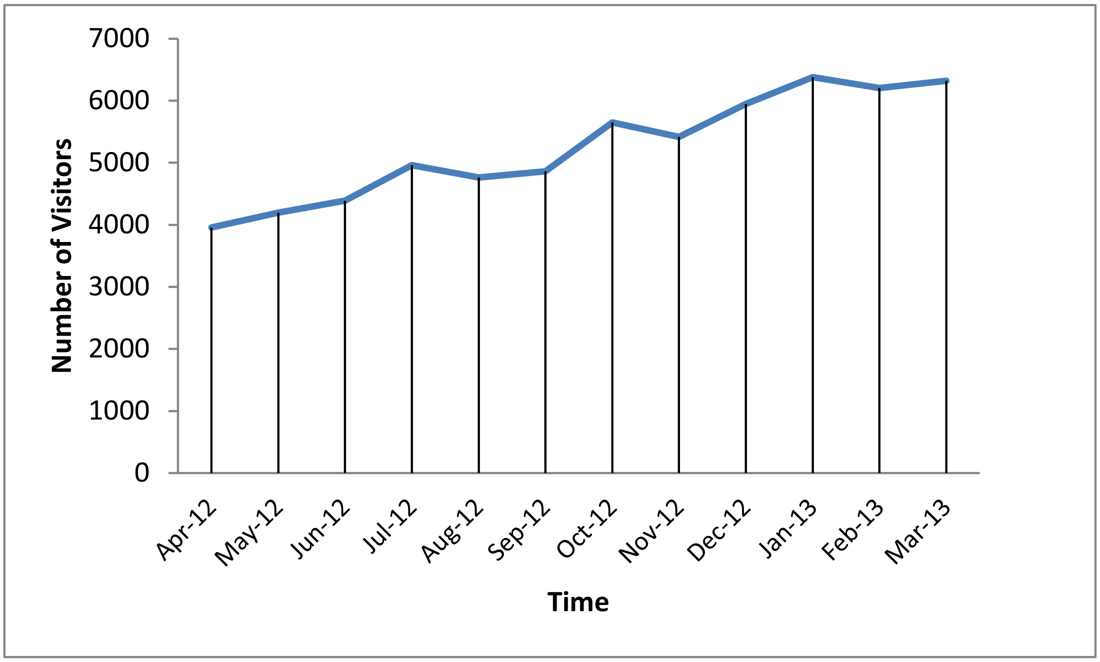
Of the identified road weather websites, only limited usage data was obtained on the RWMP website. Figure 4-4 and Table 4-5 provide summary statistics on usage over the April 2012 to March 2013 timeframe.

The growth in the usage of the RWMP website is evident from the statistics. The number of visitors to the website has increased by sixty (60) percent since April 2012. The number of hits on the websites has tripled since April 2012 and the number of page views is much higher in March 2013 than in April 2012 indicating a greater depth of use of the website. Tools provided on the website, such as the RWRI and the TMC Self-Integration Guide, have been downloaded seventeen (17) times (RWRI) and thirteen (13) times (TMC Guide) during 2010-2012.

[12] "Road Weather Management Program." Federal Highway Administration (FHWA). Last Modified July 8, 2013. http://ops.fhwa.dot.gov/weather/index.asp

[13] "Road Weather Connected Vehicle Applications." Intelligent Transportation Systems Joint Program Office (ITS JPO). Last Modified April 22, 2013. http://www.its.dot.gov/connected_vehicle/road_weather.htm

[14] http://www.clarus-system.com



Source: FHWA

Figure 4-4. Number of Visitors to RWMP Websites

Table 4-5. Hits, Page Views and Visitors for RWMP Website

Time	Hits	Page Views	Visitors
April 2012	186,773	10,559	3,957
May 2012	83,837	5,823	4,196
June 2012	106,123	7,641	4,387
July 2012	143,613	13,328	4,963
August 2012	147,105	20,143	4,765
September 2012	135,104	11,551	4,864
October 2012	178,596	13,823	5,648
November 2012	311,738	10,477	5,414
December 2012	340,170	9,956	5,947
January 2013	327,536	12,132	6,376
February 2013	422,674	16,821	6,205
March 2013	462,956	12,446	6,318
Estimated Monthly Average Growth Rate	14%	9%	5%

Source: FHWA

Summary of Performance across the Objective

The measures clearly indicate and represent the program's high level of activity in support of raising road weather knowledge and awareness around the country. Attendance in the RWMP-sponsored training activities, the use of the RWMP websites and the publication and presentation outputs of the program staff have enabled RWMP to successfully support the objective. Unfortunately, these measures only reflect the delivery of training, tools, and guidance to the community. While continued participation and use of these resources is a suitable proxy for interest, future efforts under this objective need to address the improvements in capability enabled by these resources. This may be accomplished by providing a response form for all future resources posted on the RWMP website requesting feedback on the usefulness and efficacy of the resource.

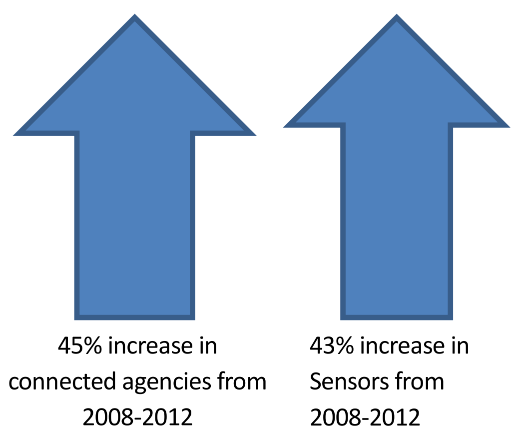
Objective 3: Advance the Collection, Processing and Distribution of Fixed and Mobile Road-Weather Observations

The early goals of promoting a national open observing system have largely been accomplished by the functional *Clarus* System. The sensor data are quality checked and made available through a national web-portal as well as subscription data feeds. The idea of utilizing passenger and fleet vehicles as weather observation probes is tantalizing due to the potential to increase the coverage and quality of the road weather observations. Already, mobile data has been reported to the *Clarus* System by several States including Minnesota, Missouri, and Nevada. Another component of this objective is to increase the use of both fixed and mobile observation in agency decision-making, traveler advisories and weather forecasting. Recent RWMP efforts in this area have included supporting *Clarus* Multi-State Demonstrations and funding eight (8) application development projects through a Broad Agency Announcement.

PM-8. Number of Transportation Agencies Participating in Road Weather Data Sharing Activities

The primary approach to road weather data sharing promoted by the RWMP has been the *Clarus* initiative. This measure tracks the number of agencies participating in the initiative to provide their environmental sensing station data to *Clarus* to share nationally.

A rapid increase in connectivity to the *Clarus* System reflects agencies' recognition of the value of sharing quality-controlled data from a variety of sources (in their States and regions). This is clearly indicated in the growth of the *Clarus* System from 2008-2012.



Source: FHWA

RWMP and *Clarus* System records show that between 2006 and 2008, the number of agencies contributing ESS data to the *Clarus* System increased from three (3) to thirty-three (33). These 33 agencies had a total of 1,700 ESS reporting to the *Clarus* System by the end of 2008. This is about

68 percent of the ESS in the country. Ten (10) agencies were pending connection to the *Clarus* System, and another eight (8) were considering connection.

From 2008 to 2013[15], the number of agencies increased from thirty-three (33) to forty-nine (49) (thirty-nine (39) State DOTs, five (5) local agencies, and four (4) Canadian provinces). These agencies connected 2,437 ESS to *Clarus*, for a total of 54,251 individual sensors. This represented a forty-five (45) percent increase in the number of agencies and a forty-three (43) percent increase in the number of sensor stations in the four years since performance measurement began. In addition, ten (10) agencies are pending connection (six (6) State DOTs, three (3) local agencies, and one (1) Canadian province) to the *Clarus* System and another three (3) agencies (two (2) State DOTs and one (1) local agency) are considering connection.

Clarus is transitioning to MADIS as well as being included in the Weather Data Environment (WDE), a part of the Connected Vehicle research initiative. Tracking this measure in the future might include the continued participation of agencies in the MADIS program as well as the use of the WDE.

PM-9. Number of Transportation Agencies that Subscribe to Road Weather Products and Services

This measure reflects the number of State DOTs reporting that they subscribe to various road weather products and services. These products and services support the DOT's advisory, control and treatment strategies. Various sources of weather data are available to both public agencies and the private sector including information from the NWS, the Federal Aviation Administration (FAA), sensors deployed by national and State agencies, and private-sector value-added services. The RWMP has played a vital role in the development, promotion and coordination of road weather information. Coordination with the NWS and the OFCM has helped bring the needs of the transportation agencies to the forefront, thereby enabling the NWS and OFCM to help increase awareness of the relevance of their products to the transportation community.

The RWMP seeks to encourage State DOTs and other transportation agencies to access road weather information through a wide variety of sources. This measure reflects the extent to which the major sources of weather information in transportation decision-making are being accessed by the States. The RWMP wants to see this access increasing over time; thus the measure assesses changes over time in the number of States that acquire various sources of information, as well as the increased diversity of information that States are using. Increases in both the number and nature of subscribed road weather products point to growing sophistication in the road weather community regarding the acquisition and use of these data.

Data on this measure were collected through the ITS Deployment Statistics survey in 2004 and 2007, but a comparable survey has not been conducted since then. The 2007 data have been supplemented in 2013 by an RWMP performance survey of State DOTs (see Appendix A for complete results from this survey). Figure 4-6 shows the percent of State DOTs that used selected sources of road weather information in 2007 and 2013. The data show small increases in rates of access to most of the information sources. Because these data are derived from two different kinds of surveys with different sets of respondents, the results are not fully comparable. Nevertheless, the questions

[15] Pisano Paul. Federal Highway Administration, Road Weather and Work Zone Management. "Dealing with Extreme Weather: Improving Transportation Resiliency, the Role of FHWA Road Weather Management Program" June 12, 2013.

asked were similar in each period. In an effort to make the two data sets as comparable as possible, only the northern tier States that responded to the 2013 survey were selected from the 2007 respondents. The results confirm these States widely use the NWS, with 100 percent of respondents in the 2013 survey indicating they access the NWS. Assuming some amount of measurement error in the data, it seems appropriate to conclude that access to most of these various sources has increased slightly or leveled off over the past six years. In addition to use of the NWS, close to 80 percent of the State DOTs (composed in the 2013 survey of predominantly northern tier States) use their own field sensors, their field personnel, and private service providers for the bulk of their road weather information needs. Questions in the 2013 survey about use of agency sensors (93 percent use) and national sensor data (63 percent use) were not asked in the 2007 survey. As shown in Figure 4-5, State DOTs use road weather data from the FAA and United States Geological Survey (USGS) to a much lesser degree, with only small increases in use since 2007. The 2013 survey indicates that awareness and use of NWS road weather data is essentially universal in the northern States where winter weather conditions are a major concern. The increased access to all these sources implies a widespread awareness of weather products and information sources along with the increasing relevance of these products in State transportation operations.

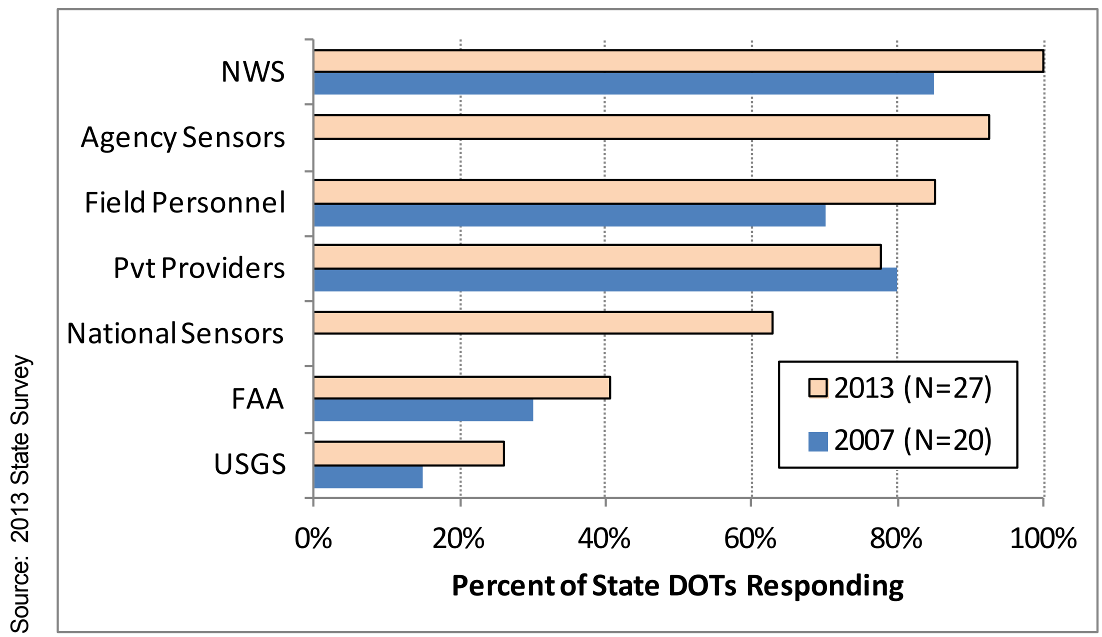


Figure 4-5. Percent of States that Subscribe to Road Weather Products and Services by Providers: 2007 and 2013

PM-10. Number of Agencies Collecting Mobile Observations of Road Weather Data from Vehicle Fleets

This measure tracks the growth in the collection and use of mobile observations of road weather data from vehicle fleets. Mobile road weather observations can include not only vehicle location data from Automatic Vehicle Location (AVL) systems or radio communication between the driver and the maintenance center but also more detailed maintenance vehicle information such as plow status and material usage, and/or road weather measurements, such as pavement surface and air temperatures.

Systems to provide these data are built into the vehicle and include wireless transmission to a central dispatch in real- or near-real time.

The idea of utilizing passenger and fleet vehicles as weather observation probes is tantalizing due to the potential to increase the coverage and quality of the road weather observations. Resting on the connectivity offered by rapidly evolving communication technology, the use of mobile observations for road weather management is closely linked to the Connected Vehicle research initiatives. The vision espoused by the program is that mobile observations will offer higher resolution observations that spatially augment fixed sensors. Four major activities/projects are of interest for the performance measures update.

- Integrated Mobile Observations (IMO) – This program seeks to collect data from maintenance fleets that are equipped with AVL/MDSS and other sensors. Results from the program will help develop the requirements for data and communication requirements, enhance and expand the post-processing algorithms to turn the data into weather observations, and tie these observations to existing weather networks. Under the IMO project the RWMP is working with several States, such as Nevada, Minnesota and Michigan, to collect mobile observations from their DOT vehicle fleets. More recent research indicates that other States are developing or deploying similar capabilities.
- Vehicle Data Translator (VDT) Research – Translating the point data coming from vehicles to meaningful quality-checked information is the goal of the VDT research. The VDT provides a way to assimilate mobile data into existing fixed stations to generate basic and advanced road segment information.
- Dynamic Mobility Applications – Collecting mobile observations and transforming them into useful weather observation models is one part of the challenge. The second part relates to the use of such observations in weather-related mobility applications.
- Inclusion of maintenance vehicle observations into *Clarus* System – Early efforts to expand the coverage of the *Clarus* System to include data from AVL-equipped snow plows have begun with one State currently providing mobile data into the *Clarus* System.

Prior to the implementation of the 2013 State DOT survey, there were no publically available data sources to quantify this measure, as this is an emerging research area for the RWMP. Increased use of mobile observations will support a wide variety of strategic and tactical decision-making for State DOT maintenance and traffic operations.

Twenty-seven (27) State DOTs responded to these two questions. As can be seen from Figure 4-6 and Figure 4-7, the response patterns were almost identical, though many individual DOTs responded differently with regard to their reported percent of vehicle fleets that collect these kinds of data.

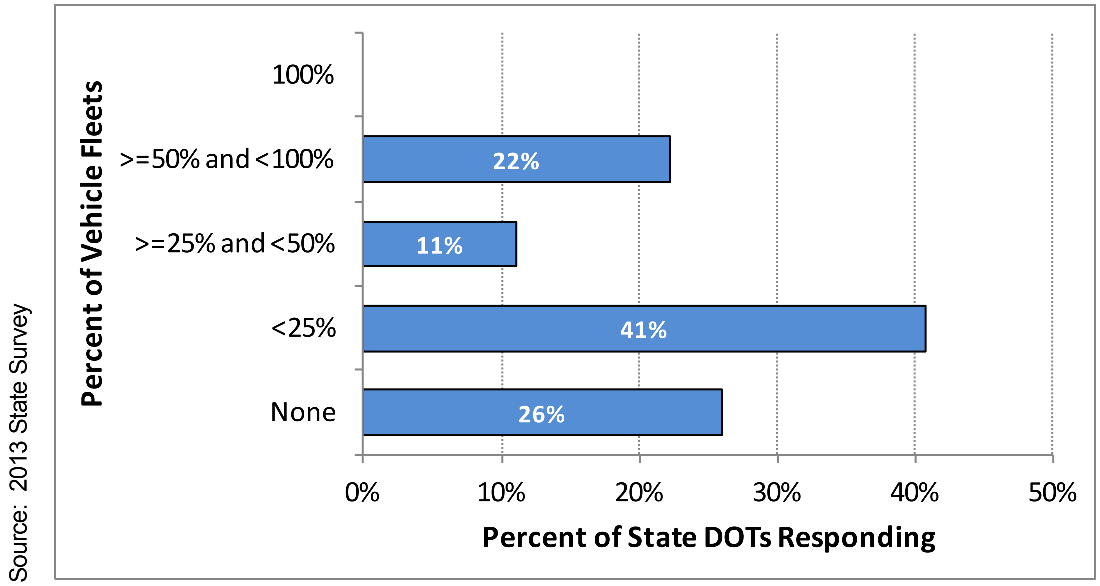


Figure 4-6. Percent of State DOTs Indicating the Percent of their Vehicle Fleets that are Used to Collect Maintenance Data in Real Time: 2013

Overall, however, about a quarter of the DOTs said that half or more of their vehicle fleets collect maintenance, weather and road weather data, and about a quarter said none of their vehicles collect these data. The good news is that 3 out of 4 State DOTs are using these road weather data collection strategies in some of their vehicles. As one State respondent pointed out, many of the vehicles in their fleets would be inappropriate candidates for such data collection, such as cars or mowing vehicles, and that individual interpreted this question as referring to winter road maintenance vehicles. It is assumed most respondents made a similar interpretation, and it may be unreasonable to expect that any DOTs will collect mobile road weather data from 100 percent of their vehicles. The RWMP encourages every DOT to install systems to collect road weather data where it can support their operations. These results suggest the majority of State DOTs are doing that, and there is potential for more DOTs to collect such data as well as for those DOTs that are collecting some mobile data from some of their vehicles to increase that with a higher proportion of their vehicle fleets.

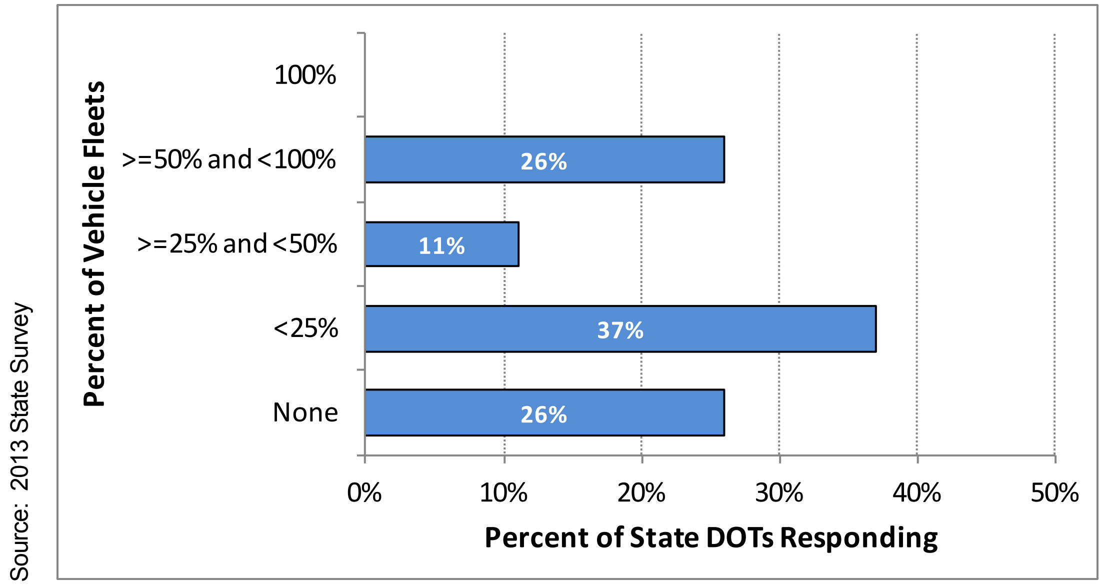


Figure 4-7. Percent of State DOTs Indicating the Percent of their Vehicle Fleets that are Used to Collect Weather and Road Weather Data in Real Time: 2013

PM-11. Number and Distribution of Fixed Environmental Sensor Stations (ESS)

This measure calculates the number and locations of fixed ESS sensors that exist in the country. At a basic level, the number of ESS deployed is a straight-forward measure of road weather interest by State DOTs. While the growth in this number over the years is an important statistic, it can be misleading in several aspects. First, since many States have already deployed ESS, the number of ESS in those States is not expected to increase substantially in the coming years. Second, these ESS might not be used in support of operations.

The number of ESS deployed has been tracked by the FHWA RWMP for the past ten years, thereby providing a historical growth record over this period. The RWMP estimated that as of June 2008 there were 2,499 ESS of which 2,017 are part of a RWIS. The remaining ESS are either part of localized agency use or not configured as part of a Statewide network. As of 2012, agencies have connected 2,435 ESS to *Clarus*. Given the nature of ESS deployments, a major increase in the overall number of stations is not expected.

Summary of Performance across the Objective

Activities under objective #3 have been very successful for the program. The success of the *Clarus* System in developing a national quality-checked observation system cannot be understated. Fixed observations through RWIS are widely used across the country routinely in operations. While improvements are still possible in the level and the quality of use of RWIS data nationally, the program has rightly shifted focus towards advancing the collection, processing and distribution of mobile observations. Currently, the survey reveals a low level of usage of mobile data in operations. However, with the decommissioning of *Clarus* and its subsequent reincarnation as an operational environment under MADIS and a research environment as part of the Weather Data Exchange, the program needs to ensure that the collection, processing and distribution of quality-checked fixed observations do not suffer.

Objective 4: Increase the Use of Weather-based Decision-support Tools and Dynamic Mobility Applications

Making systems management and operations-related decisions based on road weather observations and forecasts continues to be a challenge for many State and local agencies. The impact of weather on traffic conditions is not simple or homogenous. Since the beginnings of the RWMP, it has been working with researchers and universities in the US and abroad to collect and analyze data and develop models and tools to improve the analysis, modeling and prediction of traffic flow in all types of weather conditions. The RWMP also continues to support MDSS. Since the creation of the functional prototype, various private sector providers now offer MDSS capabilities to the States. The number of States that now operationally use MDSS is growing. Recent RWMP activities focused on advancing the use of weather-based decision support systems such as those developed under the *Clarus* Multi-State Demonstration projects and the research applications developed as part of the *Clarus* BAA. Among the many activities supported by the BAA and the regional demonstrations, the following list all the decision-support related tools developed as part of the efforts. These activities have developed the following tools to provide decision-support capabilities to agencies:

- Seasonal Weight Restriction Tool
- Multi-State Control Strategy Tool
- Non-Winter MODSS
- Integrating *Clarus* Data in Traffic Signal System Operation: A Survivable Real-Time Weather Responsive System
- The Integration of Multi-State *Clarus* Data into Real-time and Archived Regional Integrated Transportation Information System (RITIS) Data Visualization Tools
- Integration of *Clarus* System data with the New York State DOT road weather alerting system.
- Integrating *Clarus* Weather Station Data and State Crash Data into a Travel Decision Support Tool
- Other emerging areas relating to Connected Vehicle research such as Dynamic Mobility Applications

Measures under this objective trace the adoption of three categories of decision-support:

- MDSS for winter maintenance
- Other weather-related operations
- Traffic modeling and analysis

PM-12. Number of Agencies Adopting MDSS Technologies and Methods

This measure tracks the adoption of MDSS to improve maintenance practices at both strategic and tactical levels of traffic operations. Evaluations of MDSS technologies and methods have shown significant benefits to State and local agencies in terms of labor and material cost savings, and improved traffic management. Growth in the adoption of MDSS indicates that more State DOTs and transportation agencies are moving towards advanced approaches to managing their maintenance decisions and traffic operations during winter weather events.

The RWMP began advocating the adoption of MDSS technology in 2004, and since then many of the northern tier State DOTs have adopted MDSS technology; however, some adopting States had not yet implemented MDSS, or have only used this tool on a limited basis. By 2008, 30 State and local agencies reported some use of an MDSS (either the pooled fund version or the DTN/Meteorologix version), either in terms of partial geographic coverage or usage of only parts of the software system. Of those, only five agencies reported operational use as part of their regular winter maintenance operations and decision support. Operational use means the system is being used as part of regular winter maintenance by the operational component of the agency to support decision making.

In order to update this important performance indicator, the 2013 survey included a question about State DOT use of the MDSS decision support tool, with a focus on the extent of deployment and use.

As shown in Figure 4-8, almost three-quarters (74 percent) of the State DOTs responding to the 2013 survey said they either have in place (fully or partially deployed), are considering, or need an MDSS, and 26 percent reported that they don’t need an MDSS. In 2008, five State agencies reported regular operational use of an MDSS system, and in the 2013 survey, seven of the responding State DOTs reported Statewide use.

While the 2013 survey did not cover all the States (or even as many covered in 2008), these results suggest that usage of MDSS technology has expanded over the past five years. Given that nine responding State DOTs in 2013 said they either use MDSS partially or are considering deployment, there is clearly further room for expansion in the use of this beneficial tool.

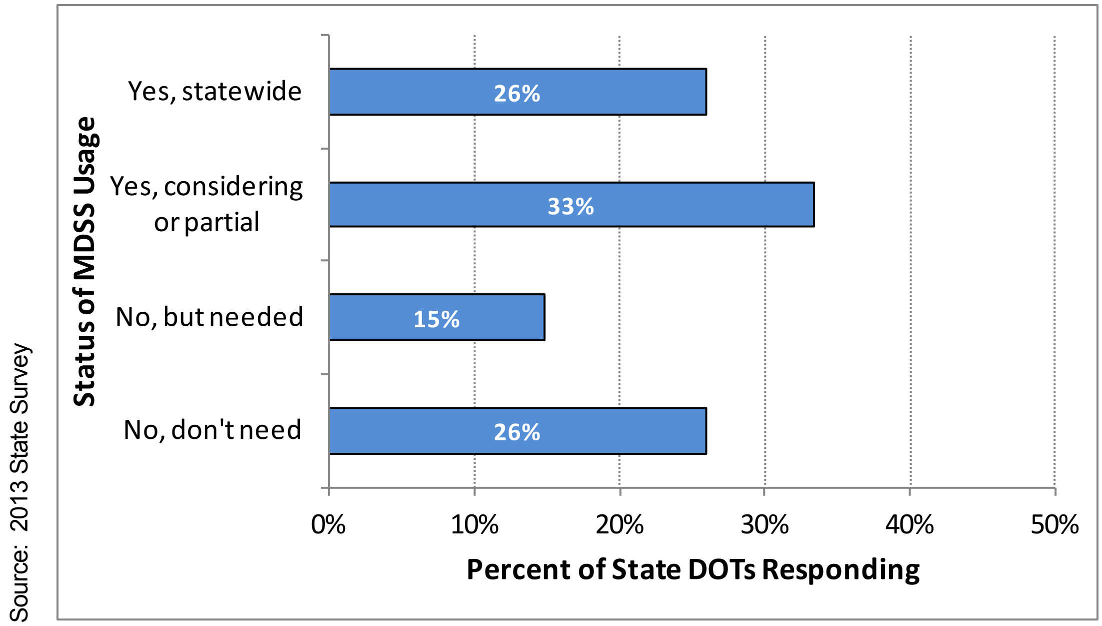


Figure 4-8. Percent of State DOTs Indicating Use or Non-use of MDSS: 2013

PM-13. Number of Agencies Using Other Weather-related Decision-support Tools

This measure focuses on the adoption of operations decision support tools for weather other than MDSS. These include seasonal load restriction tools, road weather forecast tools, and other applications developed as part of the *Clarus* Multi-State Regional Demonstration projects and the *Clarus* BAA projects. Increases in this measure point to a growing use of decision-support tools to plan and respond to a wide variety of weather conditions beyond snow and ice control.

As shown in Figure 4-9, most State DOTs (ninety-six (96) percent in the 2013 survey) are offering traveler information to assist drivers, especially during weather events. To increase the effectiveness of their operations, over three-quarters of the State DOTs (seventy-seven (77) percent) report that they actively coordinate with other jurisdictions and agencies. Almost two-thirds of the DOTs (sixty-two (62) percent) use decision support tools for non-winter maintenance, a trend that has been growing over the past decade. A similar portion of the DOTs use decision support tools for traffic control and management during adverse weather. A little more than a third of the State DOTs (thirty-eight (38) percent) employ seasonal load restrictions on commercial carriers in order to protect the integrity of their pavements during freeze-thaw cycles associated with the winter travel season.

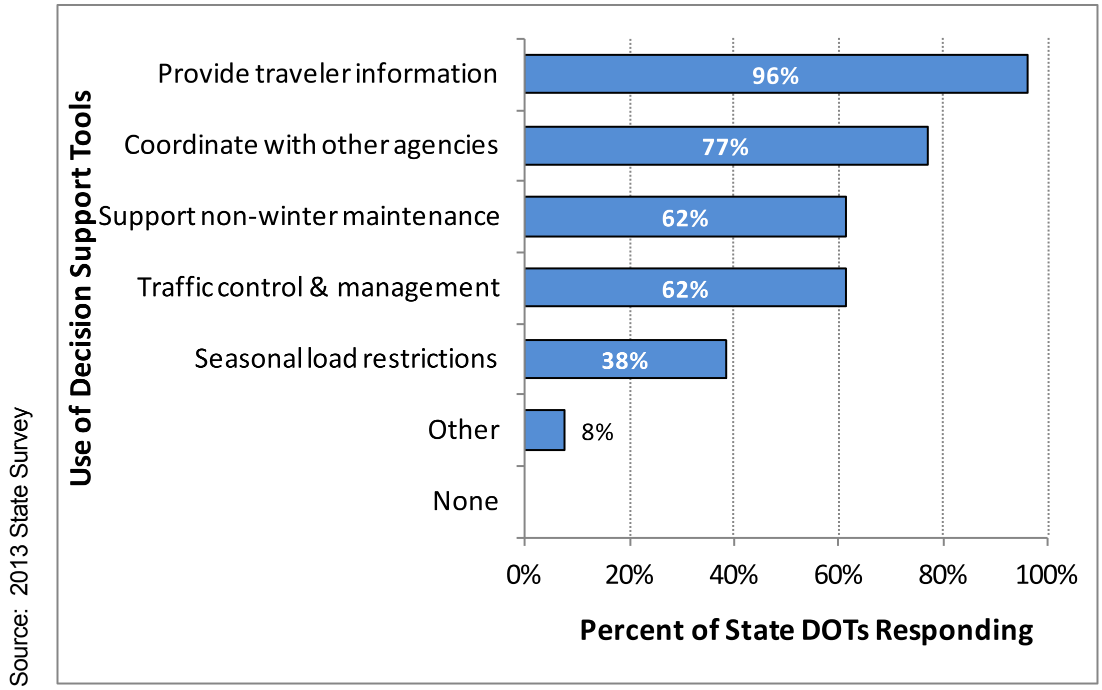


Figure 4-9. Percent of State DOTs Indicating Uses of Decision Support Tools for Road Weather Management: 2013

Figure 4-10 shows that all but one of the responding State DOTs are using more than one of these tools, and over three-quarters (77 percent) report using three or more of them. The current evidence suggests that State DOTs are using a wider array of decision support tools now to support their road weather management practices, and the use of some of these tools is becoming increasingly widespread.

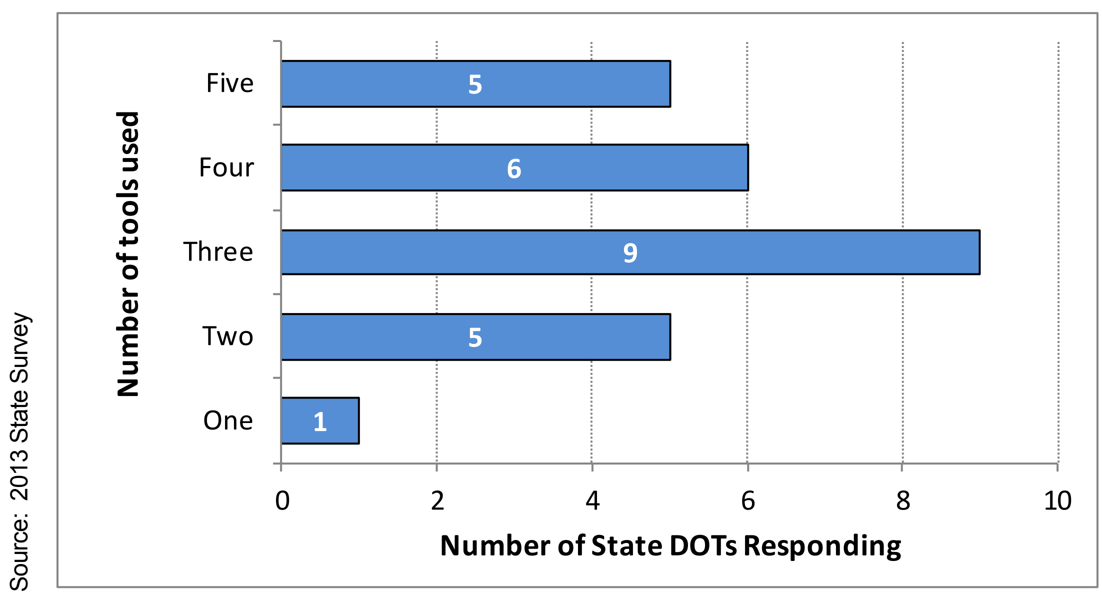


Figure 4-10. The Total Number of Other Decision Support Tools Used by Each State DOT: 2013

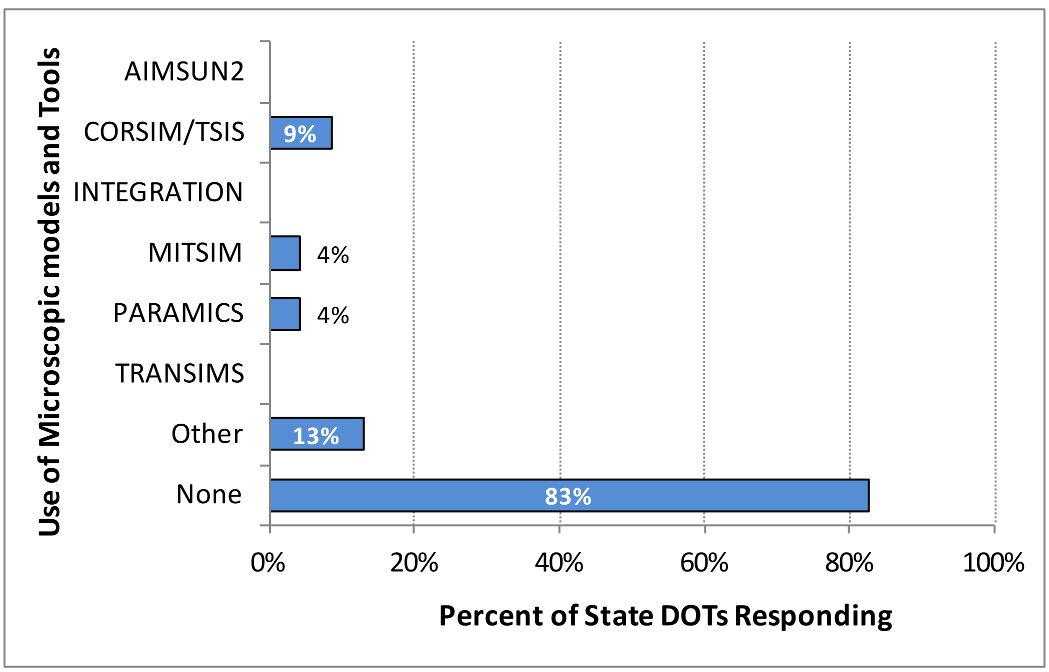
PM-14. Number of Agencies Using Weather-responsive Traffic-related Analysis, Modeling, Simulation and Decision-support Tools

This measure tracks the use of weather-responsive traffic modeling and analysis tools that enable an agency to appropriately incorporate weather impacts into the analysis. The RWMP modified two TrEPS prototypes -- DYNASMART-P, a system for transportation planning, and DYNASMART-X, a real-time system for predicting traffic conditions and patterns -- to account for weather impacts, improving their traffic estimation and prediction capabilities and overall utility.

Since 2010, RWMP research has included calibration, testing and evaluation of these weather-sensitive TrEPS models in three cities around the US (Salt Lake, New York-Long Island and Chicago).

Most traffic models that are used today assume perfect weather, leading to an inadequate analysis of weather impacts and strategies. As more agencies become aware of and start using weather-responsive traffic analysis tools, the implementation and evaluation of WRTM strategies will improve. As of 2013, there are only a few agencies that are using weather-responsive tools for traffic analysis, simulation and modeling. However, given that there are many microscopic and mesoscopic traffic analysis and modeling tools that can be customized for State DOT applications, there might be localized instances of agencies conducting research or supporting the development of these tools.

Results from the survey are shown in Figure 4-11 and Figure 4-12 below. Current usage of microscopic and mesoscopic traffic analysis models and tools is very low among the responding State DOTs, and the great majority of the DOTs report using no traffic models (83 percent for micro and 86 percent for meso). There is, however, usage by three of these State DOTs (one reported using four different models and another seven). A few of the respondents said they were unaware whether or not their State DOT was using any of these tools. There remains significant potential for more widespread use of these models and tools especially for weather-related applications.



Source: 2013 State Survey

Figure 4-11. Percent of State DOTs Indicating Use or Development of Microscopic Traffic Models and Tools for Road Weather Management: 2013

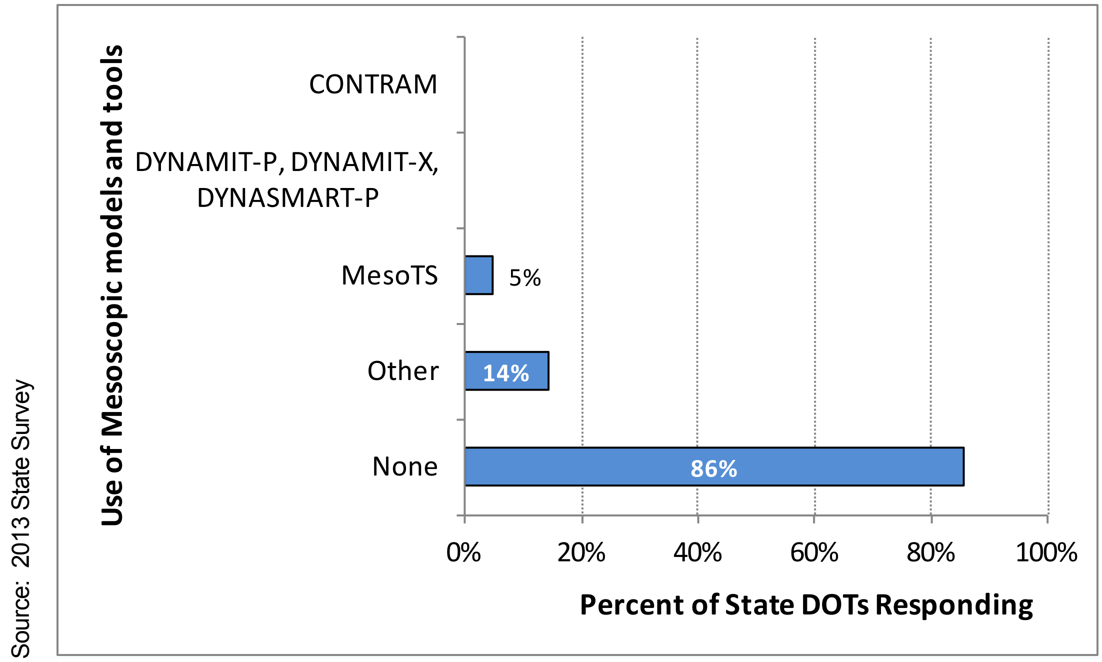


Figure 4-12. Percent of State DOTs Indicating Use or Development of Mesoscopic Traffic Models and Tools for Road Weather Management: 2013

Summary of Performance across the Objective

Increasing the use of decision support systems to increase the road weather management stakeholder community's overall capability to proactively respond to weather events is the focus of the activities carried out under the objective. As the performance measures indicate, there has been a clear growth in the adoption of MDSS around the country from 2008. This is a positive step towards reducing maintenance costs while providing enhanced levels of service to the travelers. States also reported using various other decision tools as part of their road weather operations. While it is not clear what tools they meant, the categories indicated by the respondents are certainly on track with the goals of the RWMP. The next big challenge for the program is to encourage a more analytic approach to road weather management through the use of analysis, modeling and simulation tools. Currently, the level of usage is very low across the nation.

Objective 5: Develop and Support Operational Deployment of Advanced Road Weather Management Strategies

Road Weather Management strategies are at the heart of the program as they support the ability of agencies to provide travelers with safe, reliable travel options during adverse weather. The RWMP continues to review current practices, document the benefits of existing approaches, and identify needs, such as strategies applicable for use on arterials, freeways, and rural roads. In 2011, a comprehensive set of WRTM improvements was compiled by the RWMP. The report[16] details what strategies exist, where they have been used, the benefits realized, and how to improve, implement, and evaluate them as part of their operations. Similarly, best practices for RWMP were compiled in 2013. These provide discrete examples of operational deployment of advanced road weather strategies. At a metropolitan level, the OEI provides a good summary of deployment but does not get into details of the strategies. The OEI, a qualitative assessment conducted quarterly by the FHWA Office of Operations, is a composite index that reflects the level of deployment in the forty (40) largest metropolitan areas across the country. Three weather-related questions support the calculation of the measure.

1. Does the metro area provide current and forecast weather and road conditions on 511/HAR, public websites and message signs?
2. Are they implementing traffic control in response to weather events (e.g., Variable Speed Limit (VSL), ramp metering, signal timing) and integrating weather information in their TMC?
3. Do they use weather-based decision support systems to make maintenance decisions (e.g., use the MDSS to determine staffing schedules and treatment actions for snow and ice control, determine staffing schedules for clearing debris, striping, mowing, etc.)?

[16] Federal Highway Administration. Developments in Weather Responsive Traffic Management Strategies: Final Report. June 30, 2011. (FHWA-JPO-11-086). http://ntl.bts.gov/lib/42000/42900/42965/wrtm_final_report_06302011.pdf

In the first and fourth quarters of Fiscal Year 2012, the following national results (Figure 4-13) were obtained for weather-related capabilities.

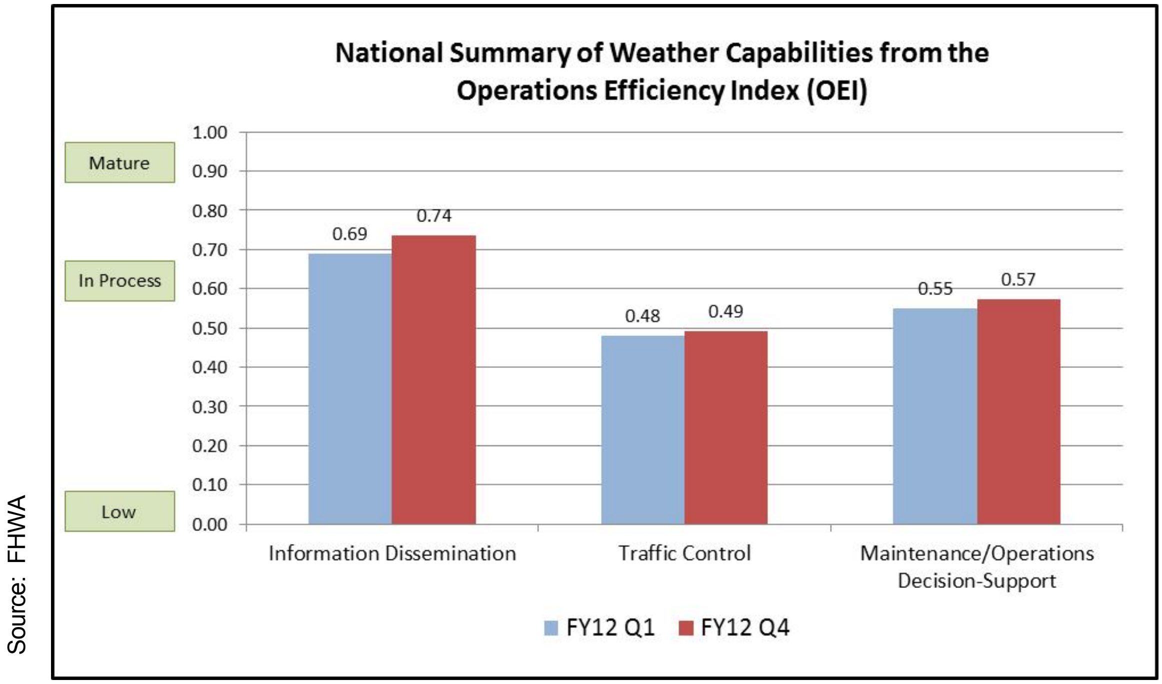


Figure 4-13. OEI Measures for First and Fourth Quarters, FY 2012

While the OEI provides a high-level summary and is a good national-level indicator, the following measures assess the overall level of deployment of these strategies across the nation at a greater level of detail.

PM-15. Number of States Disseminating Advisory Weather and Road Weather Information to Travelers

This measure focuses on State DOTs providing road weather advisory information to travelers. Advisory information may include cautionary messages, weather advisories, travel times, accident reports, pavement surface conditions, or routing and diversion information. These include both pre-trip and en-route messaging to travelers. Effective messaging to travelers is an essential part of road weather management. This measure assesses the level of deployment nationally in providing advisories to the traveling public. Figure 4-14 shows the number of States reporting that they provide advisory weather information using four different technologies including Dynamic Message Signs (DMS), Highway Advisory Radio (HAR), 511 phone system, and traveler information website in 2004 and 2007. The source of the data is the ITS Deployment Statistics Survey. The dotted portion in each bar in the figure indicates use of the above systems but without provision of weather information. An assumption was made that if agencies were disseminating information in 2004, they would continue to do so if there was no response from the State in 2007 for the survey. If there was no response in 2004, 2007 data were omitted for that State.

Weather information types that are being disseminated to travelers include:

- Atmospheric observations (e.g., precipitation and air temperature from ESS and airport observations).
- Atmospheric conditions (e.g., sky conditions, precipitation, wind speed/direction, and air temperature from analyses of observed weather data).
- Route-specific pavement condition data (e.g., dry, wet, icy, compact snow, plowed, flooded).
- Video images of selected routes.
- Weather-related travel restrictions (e.g., tire chain requirements, closed routes).
- General weather advisories (e.g., NWS watches and warnings).
- General weather forecast data (e.g., weather service provider generated weather forecasts).
- Route-specific road weather forecasts.

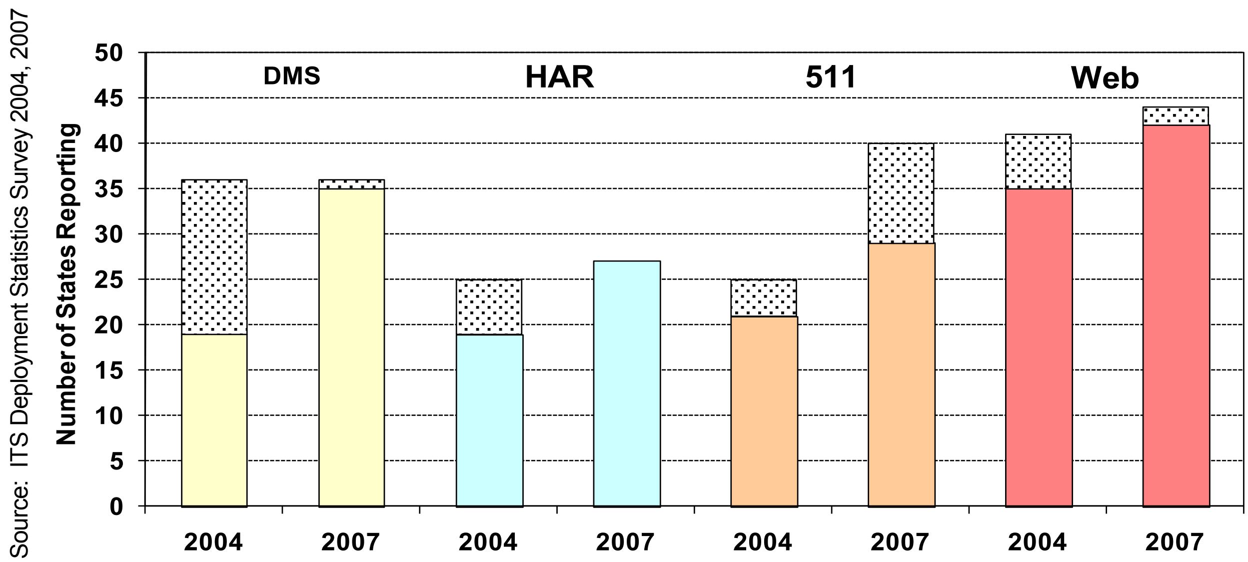


Figure 4-14. Number of State Agencies Disseminating Road Weather Information to Travelers, by Year and Technology[17]

The data in Figure 4-14 show that dissemination of road weather information to travelers has increased between 2004 and 2007 for each type of information distribution technology, though the total use of these technologies (for both road weather and non-weather information) has changed little during this period, except for an increased use of 511 systems.

Figure 4-15 provides more detail about changes in the kinds of road weather data shared with travelers during this period. There were significant increases in the types of road weather data and information being disseminated across all information types between 2004 and 2007.

[17] Survey Question – "Does your agency provide road weather information to the traveling public? If Yes, Please specify the type of dissemination system(s). (Check all that apply)."

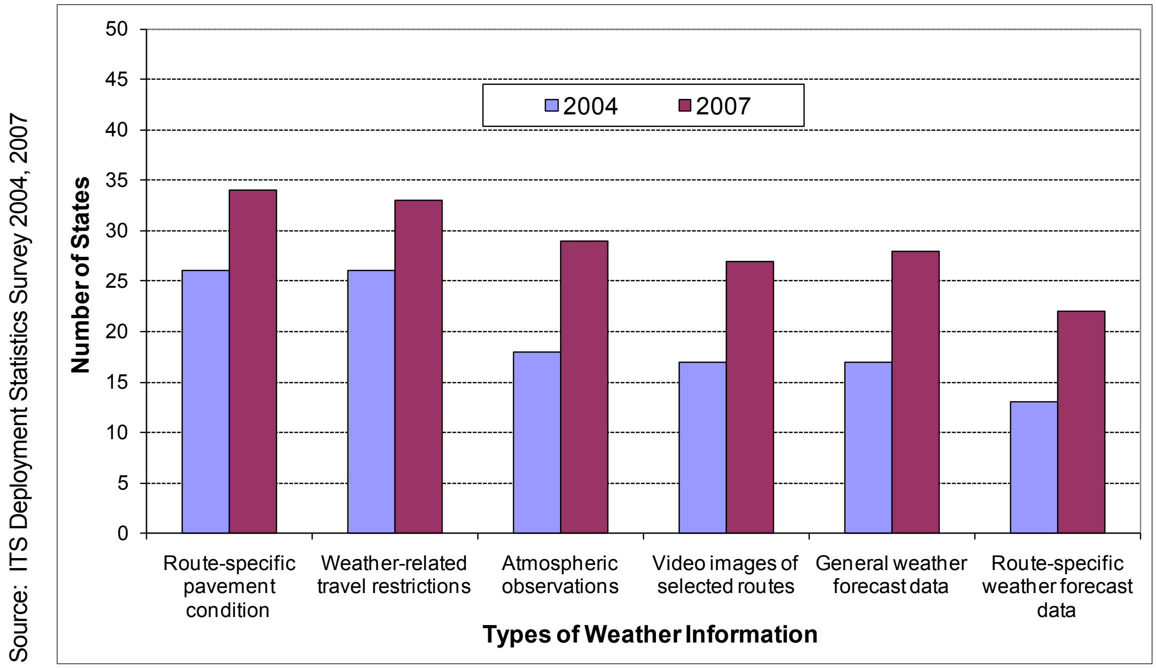
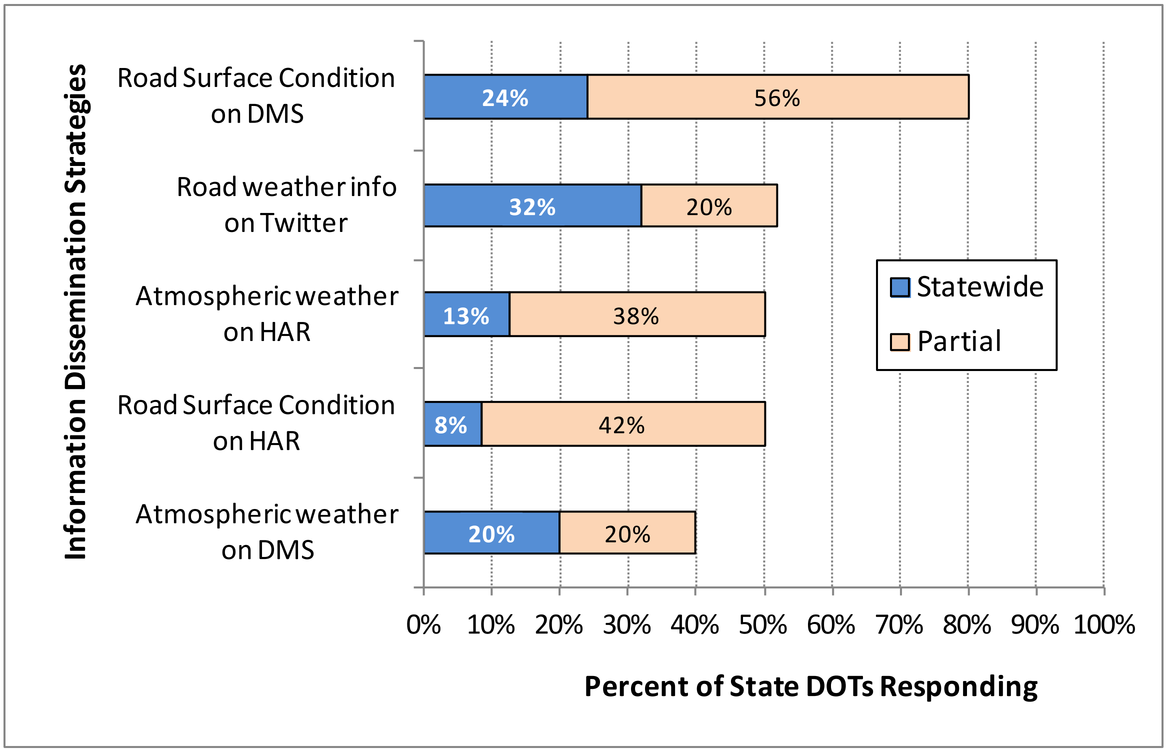


Figure 4-15. Number of States Disseminating Different Types of Weather Information: 2004 and 2007[18]

As has been the case with the other measure, these questions were not included in the 2010 version of the ITS Deployment Survey. Several questions related to the provision of traveler information were posed in the 2013 survey of State DOTs.

Figure 4-16 shows the results of State DOT responses to this set of five questions. While some States are disseminating road weather information Statewide using DMS, HAR and Twitter, many report that they have only limited or partial deployment of this information. As shown in Figure 4-16 for most of the dissemination strategies, about half of the surveyed State DOTs have not yet deployed these strategies in relation to weather. Nevertheless, the current survey results show further progress since 2007 in the deployment of road weather information to the traveling public, though direct comparisons are difficult given differences in the surveys conducted in 2007 and 2013 and the response rates for these surveys.

[18] Survey Question – **"**Please specify the type of road weather information disseminated to the traveling public (Check all that apply)."



Source: 2013 State Survey

Figure 4-16. Percent of State DOTs Indicating Extent of Deployment of Selected Information Dissemination Strategies: 2013

PM-16. Number of Agencies Using Control and Treatment Strategies during Weather Events

Control strategies include, among others, speed control, diversions, vehicle restrictions, and signal timing changes in response to weather conditions. This performance measure determines the level of use of these strategies nationally. Control strategies, similar to advisory strategies, are important and effective actions agencies can take in responses to all types of road weather conditions. A variety of treatment strategies such as anti-icing and use of MDSS are captured in other measures. In this measure, weather responsive traffic incident management practices can be broadly categorized as a treatment strategy.

There was limited information available for this measure in 2007 through the ITS Deployment Statistics that categorizes control strategies as VSLs, signal timing changes, and use of technology for closures and diversions. This information is not available in 2010, although use of ramp metering during weather is included. To obtain current information on State DOT use of control and treatment strategies during weather, six new questions were included in the 2013 survey.

Figure 4-17 shows the results of State DOT responses to this set of six questions. Most widely deployed, either partially or Statewide (88 percent of State DOTs), are traffic incident management practices in response to inclement weather. Adjusting signal timing at intersections in response to weather remains relatively rare, with twenty-one (21) percent of State DOTs deploying this strategy either partially or Statewide. The use of the other control and treatment strategies falls in between these two strategies, indicating that there remains substantial room for further adoption of these kinds of road weather operational strategies across the States. Of the twenty-six (26) State DOTs responding to one or more of the questions regarding the use of these six strategies, fifteen (15) said they had deployed Statewide or partially deployed three or more of the strategies, and two State DOTs reported they had not deployed any of the six strategies.

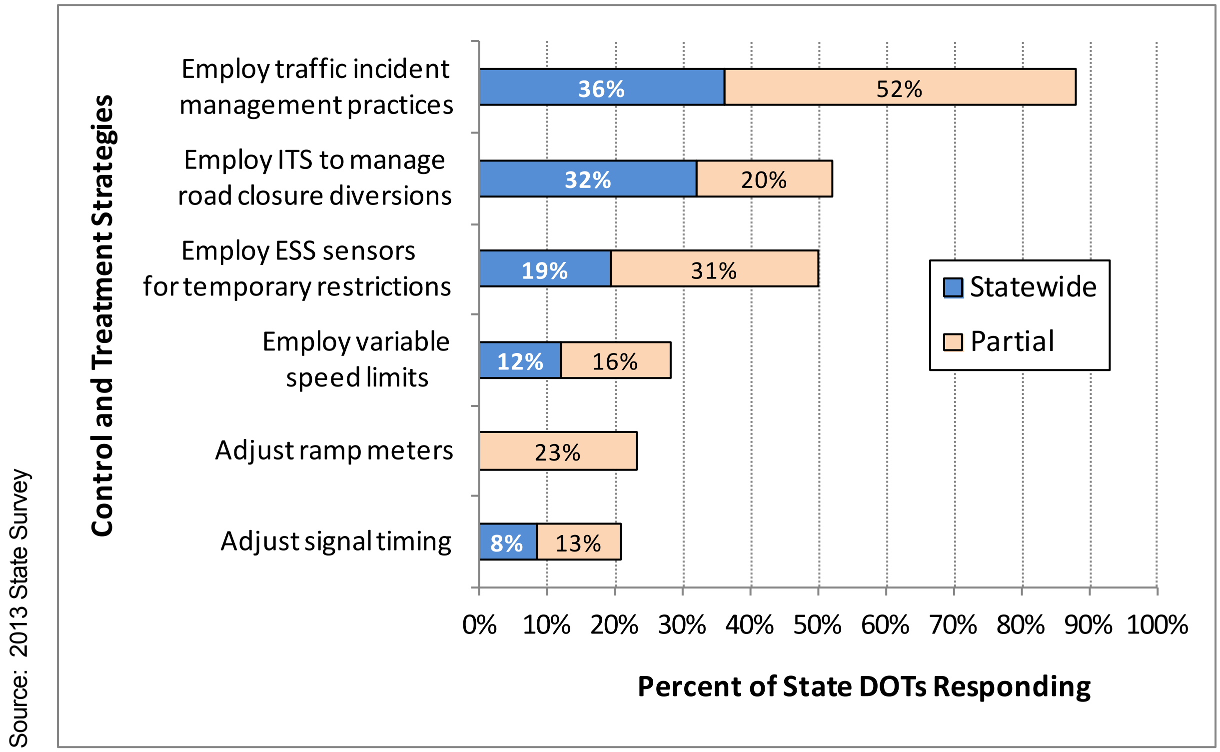


Figure 4-17. Percent of State DOTs Indicating Extent of Deployment of Selected Control and Treatment Strategies: 2013

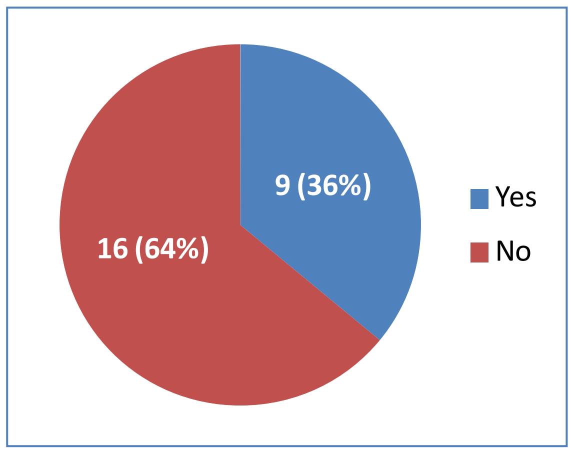
Summary of Performance across the Objective

The operational deployment of advisory, control and treatment strategies is growing nationally. Survey responses from the State DOTs indicate high awareness and utilization of several of these strategies. Importantly, there is room to improve in this objective. States report several strategies which are partially deployed. Encouraging the continuous deployment and refreshment of these strategies is important.

Objective 6: Improve Overall System Performance during Weather Events

Assessments of State DOT performance with regard to their responses or actions during adverse weather, and particularly efforts to compare performance across different locations, agencies or time periods, raise a methodological question of how to control for differences in the type and severity of the weather events. The objective is to understand and measure performance in a way that reflects the effectiveness and impacts of the agency's actions, but those effects are significantly influenced by the weather itself. In order to control for the effects of weather, it will be helpful to have available a consistent measure of weather severity over time. Some States have developed or adopted a "winter severity index" so they can more properly compare their agency's performance across different events or from one winter season to the next, recognizing that a mild winter one year and a severe winter the next will make it difficult to independently assess agency performance and effectiveness if those weather severity differences are not taken into full account in the comparative analysis.

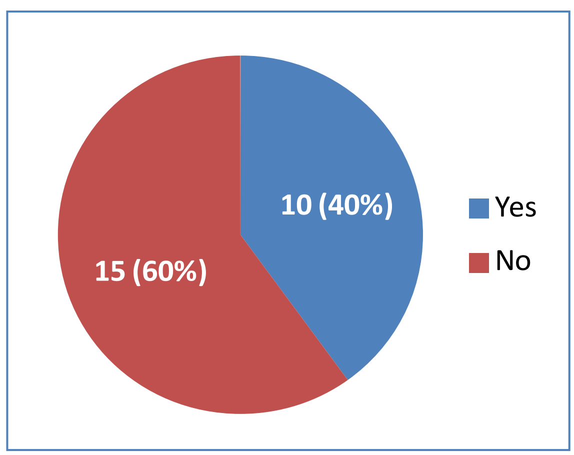
A survey question in 2013 was intended to gather information on the extent of State DOT usage of a winter weather severity index. Responses to this question are shown in Figure 4-18. Only seven of the State DOTs responded to the request for a link or reference to their index, but most said they were considering such an index or were in the process of developing it. See Appendix A for more details.



Source: 2013 State Survey

Figure 4-18. Does your State DOT Calculate a Winter Severity Index?

Finally, the 2013 survey asked State DOTs whether they published an annual report that includes winter maintenance performance measures they use in their DOT to assess performance. Figure 4-19 summarizes the responses. Out of the 25 State DOTs that answered both of these questions, eleven of them responded "No" to both these questions; that is, 44 percent of the northern tier State DOTs surveyed are neither using a winter severity index nor publishing winter maintenance performance measures. Six State DOTs (24 percent) answered "Yes" to both questions, and thirteen (13) (fifty-two (52) percent) said "Yes" to one or both of these questions.



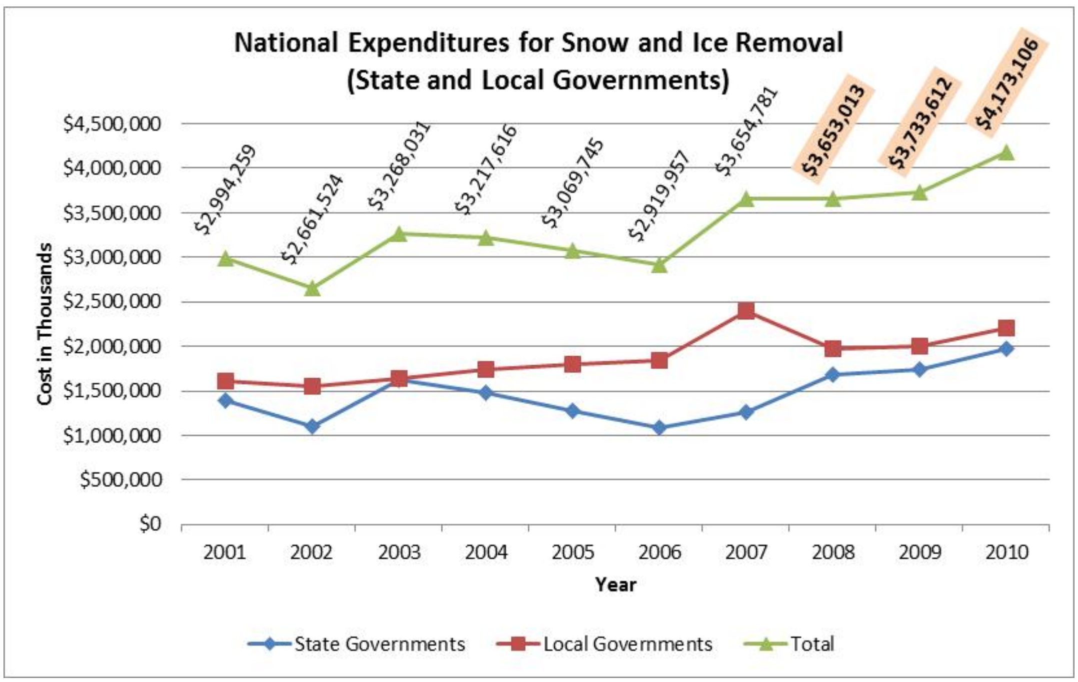
Source: 2013 State Survey

Figure 4-19. Does your State Publish Winter Performance Measures?

The reason to present these charts under this objective is to underscore the difficultly in comparing or collating the agency-level or in some cases, project-level or site-level improvements. As the discussion of the performance measures under this objective illustrate, the performance of the RWMP can be measured in some instances most appropriately not by overall national-level numbers but by isolated success stories throughout the nation.

PM-17. Reductions in Agency Costs of Weather-related Maintenance and Operations Activities

This measure tracks the cost of winter maintenance activities (identified as snow and ice removal) experienced by State and local agencies on an annual basis. Weather-related maintenance costs are a significant portion of the State and local agency budgets. State and local statistics on expenditures for snow and ice removal are available on an annual basis as part of the Highway Statistics publication series,[19] a data compilation created and maintained by the USDOT FHWA Office of Highway Policy Information (OHPI). Figure 4-20 shows the national expenditures for snow and ice removal for a 10-year period between 2001 and 2010. The previous FHWA RWMP Performance Measurement Report[20] tracked this data for the seven (7) year period between 2000 and 2007. The current report shows 10 year data updated through 2010 with the last three years (2008, 2009, and 2010) highlighted in orange.



Source: FHWA, Highway Statistics

Figure 4-20. Annual Expenditures for Snow and Ice Removal (State and Local Governments)

[19] Data Source: Highway Statistics (2001-2010), Data Tables SF-4C (Disbursements for State-Administered Highways) and LGF-2 (Local Government Disbursements for Highways). Accessed through http://www.fhwa.dot.gov/policyinformation/statistics.cfm.

[20] U.S. Department of Transportation, Federal Highway Administration (2009). Road Weather Management Program Performance Metrics: Implementation and Assessment. Report No.: FHWA-JPO-09-061. EDL #14492 (August).

These national numbers for the cost of winter maintenance activities are hard to attribute to RWMP performance. Long term trends in the data can be indicative of overall performance; however, seasonal and geographic variation in weather and road weather conditions and local practices create significant variation in the data. Regardless, the graph indicates an increasing trend in national expenditures of winter maintenance.

While the causes of winter maintenance cost increases are not easily broken down nationally, individual States have reported increased costs for winter weather operations in recent years. For example, States and cities along the east coast affected by severe winter weather, such as New York, New Jersey, Massachusetts, and Virginia, all reported exceeding their snow removal budget in recent years. According to NJ DOT, its snow bill for the 2011-2012 winter season was $50.8 million (as of early March 2013). This bill far exceeded NJ DOT's $10 million budget for snow fighting.[21] Similarly, Massachusetts spent $84 million by early March 2013 on snow removal while their budget for the entire 2011-2012 winter season was $45.5 million[22]. A report published by the National Association of State Budget Officers (NASBO), found that Virginia budgeted $94 million for snow removal for the 2009 – 2010 winter season but spent $267 million.[23]

The centerpiece of RWMP efforts to reduce agency costs for weather related maintenance and operation activities pertain to MDSS development and adoption. MDSS is intended to provide agencies with more accurate and route-specific weather forecasts and road weather condition information. This improves the timing of crew call-up and pre-treatment applications and guides decisions regarding treatments. The objective is to reduce staff and material requirements to more efficiently manage winter storm conditions and their impacts on pavement surfaces. Non-winter MDSS systems offer comparable benefits at other times of the year for activities such as pavement striping, resurfacing, and roadside maintenance.

For these reasons, RWMP is monitoring and sponsoring benefit-cost assessments of MDSS applications. Specifically, RWMP is looking at these new projects to demonstrate measurable cost savings as a way to further encourage agencies to support and fund deployment of MDSS. In addition to MDSS, the RWMP has been promoting other best practices to reduce material and labor costs. Treatment actions such as anti-icing and pre-wetting have demonstrated significant material and costs savings. Table 4-6 provides examples of State and agency cost savings using existing and new technology for winter MDSS. Several of these were reported in the previous RWMP performance measurement report with new studies added to the table.

[21] Frassinelli, M. (20 March 2013). NJ has second costliest winter for snow removal on record, DOT says. NJ.com. Retrieved 18 April 2013, from http://www.nj.com/news/index.ssf/2013/03/nj_has_second_costliest_winter.html.

[22] (18 March 2013). MassDOT to ask state for more money for snow and ice removal. WCVB.com. Retrieved 18 April 2013, from http://www.wcvb.com/weather/MassDOT-to-ask-state-for-more-money-for-snow-ice-removal/-/9850416/19363972/-/992sypz/-/index.html.

[23] National Association of State Budget Officers (NABSCO). Analyzing Costs Associated with Winter Storms. 14 February 2011. http://www.nasbo.org/sites/default/files/Analyzing%20Costs%20of%20Winter%20Storms.pdf. Retrieved 18 April 2013.

Table 4-6. Evaluations of RWMP Strategies Aimed at Reducing Material and Labor Usage

Strategy Used	Source	Reported Reduction Per Winter	Locality Reporting
Having meteorologists at TOC	Research and Innovative Technology Administration (RITA) ITS Benefits Database[24]	18 percent reduction in overall costs	Utah DOT
Agency savings per winter by using MDSS to maintain same conditions	Western Transportation Institute & Iteris, *Analysis of Maintenance Decision Support System (MDSS)* Draft Final Report, December 2008	$1,182,202	New Hampshire
		$1,573,408	Minnesota
		$1,728,292	Colorado
Agency Savings by using MDSS to make tactical shift deployment decisions	Indiana Department of Transportation (INDOT) Maintenance Decision Support System (MDSS):Statewide Implementation , Final Report for FY09, Draft, May 2009	- $1.3 million (58,274 hours) in overtime - $12 million in salt costs	Indiana
	RITA ITS Benefits Database[25]	- $95,359 Net Benefit in 2009 due to MDSS. - For every $1.00 that spent on MDSS, it achieved $1.34 in return	City of Denver
Using Environmental Sensor Stations (ESS)	RITA ITS Benefits Database[26]	$2.2 million reduction in labor and materials cost	Utah
Use of anti-icing	RITA ITS Benefits Database[27]	62 percent labor hours	Idaho
Use of living snow fences	Minnesota Department of Transportation. Technical Summary: Evaluating the Costs and Benefits of Living Snow Fences, May 2012	Assumed $1.3 million per year savings (Total winter maintenance cost)	Minnesota

Source: RITA ITS Benefits Database, Research Reports.

[24] RITA, ITS Benefits Database: http://www.itsbenefits.its.dot.gov/ITS/benecost.nsf/ID/29012E1AB352F3E7852573DE006EBE6A

[25] RITA, ITS Benefits Database: http://www.itsbenefits.its.dot.gov/ITS/benecost.nsf/ID/D3C9FBF5069A7363852577F1006F15F7

[26] RITA, ITS Benefits Database: http://www.itsbenefits.its.dot.gov/ITS/benecost.nsf/0/84686D5AF6734D2A85257894004998D9

[27] RITA, ITS Benefits Database: http://www.itsbenefits.its.dot.gov/ITS/benecost.nsf/0/443E420C4C15E1068525733A006D4A20

In 2009, the *Cost Benefits of Weather Information for Winter Road Maintenance Final Report* was published. The report provided a benefit-cost assessment for weather information in winter road maintenance using three case studies. The case studies collectively showed that winter maintenance costs decreased as the use of weather information increased or its accuracy improved. The results are summarized in Table 4-7 below.[28]

Table 4-7. Benefit-Costs of Weather Information on Winter Maintenance

Case Study State	Winter Season	Winter Maintenance Cost ($ 000s)	Benefits ($ 000s)	Weather Information Cost ($ 000s)	Benefit-Cost Ratio	Benefits/ Maintenance Costs (%)
Iowa	2006-07	14,634	814	448	1.8	5.6
Nevada	2006-07	8,924	576	181	3.2	6.5
Michigan	2007-08	31,530	272	7.4	36.7	0.9

Source: Cost Benefits of Weather Information for Winter Road Maintenance, Final Report.

Overall, the number of positively evaluated MDSS systems continues to grow. Case studies indicating the efficacy of treatment strategies are also available. Continued tracking of these success stories will point to overall progress in this measure for RWMP.

PM-18. Reduction in Number and Types of Fatalities and Crashes Attributed to Adverse Weather Nationally

On average, twenty-four (24) percent of annual crashes (resulting in injuries or fatalities) are attributed to adverse weather and its effect on visibility and road surface conditions.[29] This measure tracks the reduction in nationwide numbers and types of fatalities attributed to adverse weather. Databases like the Fatality Analysis Report System (FARS), National Highway Traffic Safety Administration's (NHTSA's) National Automotive Sampling System (NASS) General Estimates System (GES), and NHTSA's National Motor Vehicle Crash Causation Survey (NMVCCS) provide national level summaries. Table 4-8 summarizes the number of nationwide fatal crashes occurring during inclement weather (rain, snow/sleet, and other). These national level data shows that the number of fatal crashes occurring during inclement weather are generally on a decreasing trend similar to overall crashes (irrespective of the cause of incident). The rate of decrease however is slower for weather-related crashes compared to crashes as a whole.

[28] Western Transportation Institute and Montana State University. Cost Benefits of Weather Information for Winter Road Maintenance, Final Report, April 2009. http://www.westerntransportationinstitute.org/documents/reports/4w1576_final_report.pdf

[29] "How do Weather Events Impact Roads?" FHWA Road Weather Management Program. 31 Aug 2013. http://www.ops.fhwa.dot.gov/weather/q1_roadimpact.htm.

Table 4-8. Number of Fatal Crashes Attributed to Weather

Year	Fatal Crashes	Fatal Crashes During Inclement Weather	% Fatal Crashes During Inclement Weather	Total Crash Rate (Per Licensed Driver)	Weather Crash Rate (Per Licensed Driver)	Total Crash Rate (Per VMT)	Weather Crash Rate (Per VMT)
2001	37,862	4,210	11%	0.198	0.022	13.543	1.506
2002	38,491	4,351	11%	0.198	0.022	13.480	1.524
2003	38,477	4,642	12%	0.196	0.024	13.313	1.606
2004	38,444	4,761	12%	0.193	0.024	12.967	1.606
2005	39,252	4,368	11%	0.196	0.022	13.130	1.461
2006	38,648	3,807	10%	0.191	0.019	12.821	1.263
2007	37,435	3,743	10%	0.182	0.018	12.350	1.235
2008	34,172	3,796	11%	0.164	0.018	11.480	1.275
2009	30,862	3,409	11%	0.147	0.016	10.438	1.153
2010	30,296	3,064	10%	0.144	0.015	10.213	1.033
2011	29,757	3,043	10%	0.140	0.014	10.100	1.033

Sources: FARS, Highway Statistics[30]

Figure 4-21 and Figure 4-22 below show the national trends for crash rates during inclement weather conditions per thousand licensed drivers and per billion vehicle miles traveled. The figures illustrate how the crash rates are decreasing over time. However, while there is a decrease in both the overall and the inclement weather crash rates, the weather crash rate is decreasing at a much slower rate than the overall crash rate. It is noted that non-fatal crashes are not included in the quantification of the measure.

[30] Fatal Crash Data sourced from FARS "Fatal Crashes by Weather Condition: USA" (2001 – 2011) http://www-fars.nhtsa.dot.gov/Crashes/CrashesTime.aspx, Population and Vehicle Miles Traveled Information sourced from Highway Statistics Reports (2001 – 2011) Tables (DL-1C) "Licensed Drivers by Sex and Ratio to Population" and (VM-202) "Annual Vehicle-Miles of Travel." http://www.fhwa.dot.gov/policyinformation/statistics.cfm

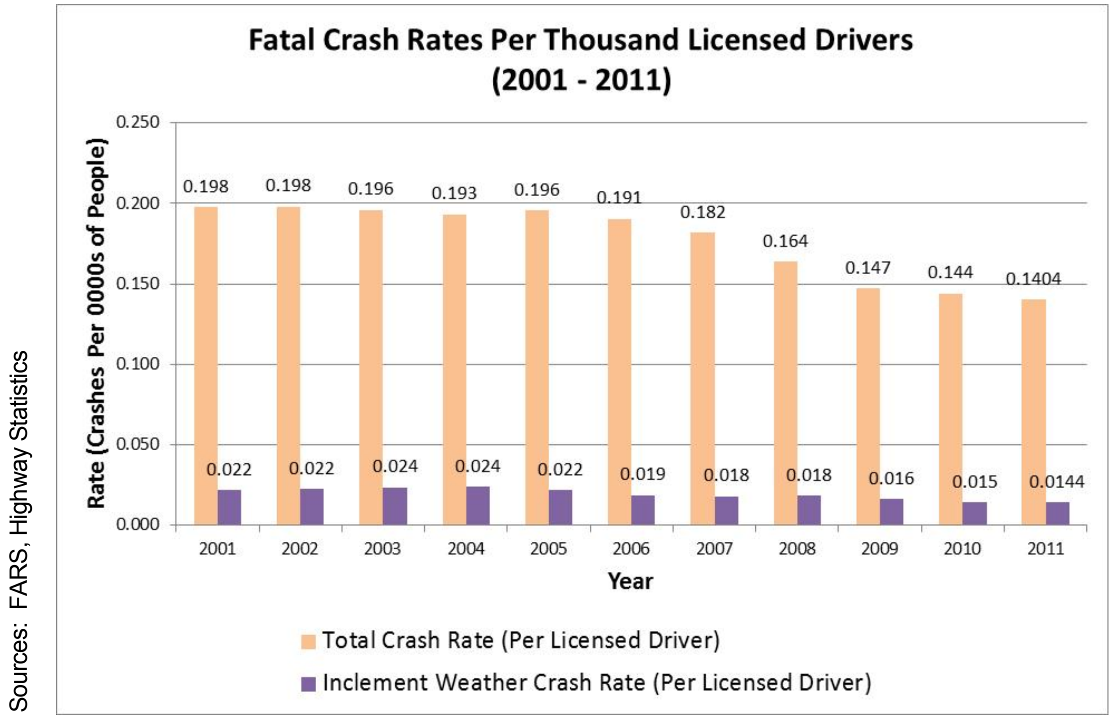


Figure 4-21. Fatal Crash Rates during Inclement Weather per 1,000s of Licensed Drivers

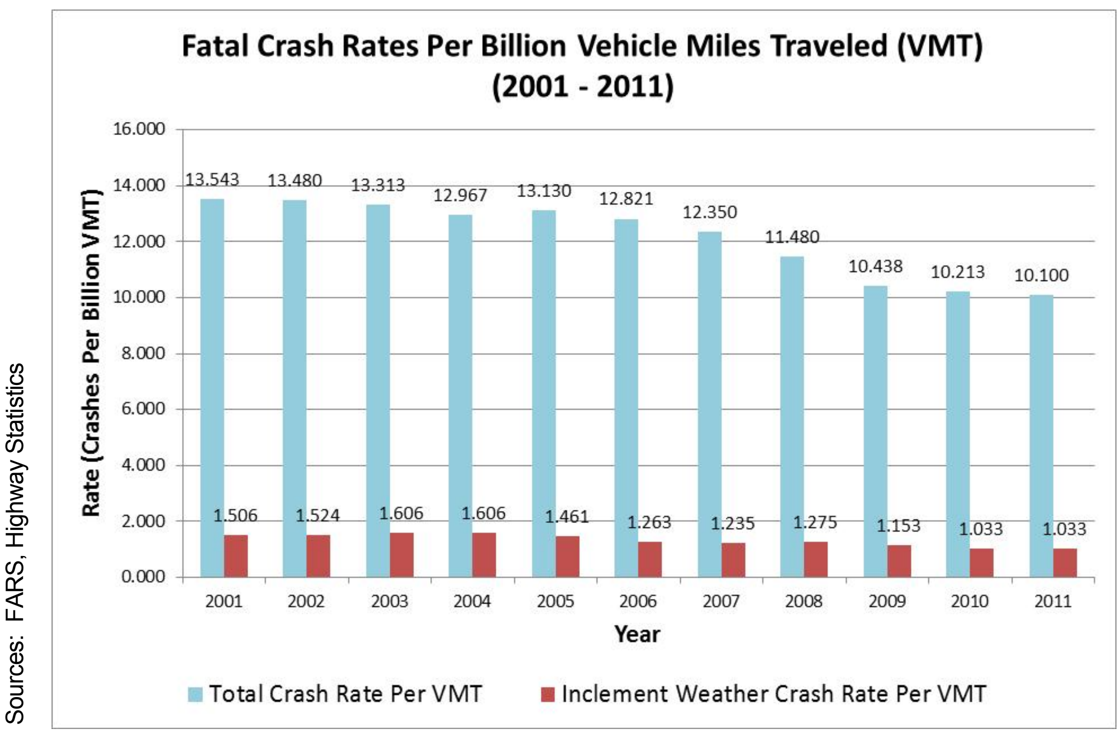


Figure 4-22. Fatal Crash Rates during Inclement Weather per Billions of Vehicle Miles Traveled

Adoption of decision support tools like MDSS can improve agency response and treatment of weather conditions, thereby reducing safety risks during inclement weather. Also, the RWMP's participation in the DOT Connected Vehicle program will directly address safety issues. Specifically, the best practice database maintained by the RMWP encourages the adoption of technologies to address fog, high wind, floods and adverse road conditions, treatment strategies such as pavement de-icing systems and MDSS, and other control strategies which have resulted in several successful deployments nationally. It is still hard to determine the contribution of specific strategies on national crash rates that can be attributed to the RWMP. However, individual success stories can be tabulated.

The primary source of data for tracking this indicator at the strategy-level comes from the US DOT Research and Innovative Technology Administration (RITA) ITS Benefits Database.[31] The data in Table 4-9 are a compilation of the benefits reported in various deployments around the country.

[31] US DOT Research and Innovative Technology Administration (RITA) Intelligent Transportation Systems Joint Program Office (ITS JPO). "Knowledge Resources – Benefits Database" http://www.itsbenefits.its.dot.gov/.

Table 4-9. Examples of RWMP Strategies Aimed at Reducing Crashes

Strategy Used	Source	Reported Reduction in Crashes	State Reporting
Low visibility/fog warning system	Best Practices for Road Weather Management, Version 3.0[32]	While there had been over 200 on I-75 crashes, 130 injuries, and 18 fatalities on this highway section since the interstate opened in 1973. By 2003, only one fog-related crash had occurred on the freeway since the system was installed in 1994.	Tennessee
Anti-icing treatment	RITA ITS Benefits Database[33]	Reduced snow and ice related crashes by 14 percent.	Denver, Colorado
Wet pavement warning systems	RITA ITS Benefits Database[34]	Reduced crashes by 39 percent.	North Carolina
Automatic bridge anti-icing system	Seasons of Achievement: Accomplishments of the Road Weather Management Program[35]	Reduced crashes by 64 percent.	Utah
	RITA ITS Benefits Database[36]	Reduced crashes at Interstate 35 bridge near Duluth by 56 percent. The benefit-to-cost ratio was 2.0:1.	Minnesota
		Reduced crashes at Truck Hwy 61 bridge near Winona by 100 percent. The benefit-to-cost ratio was 3.1:1.	Minnesota
		Reduced crashes at an intersection in Dresbach by 100 percent. The benefit-to-cost ratio was 2.7:1.	Minnesota
		Anti-icing system installed on I-35W at the Mississippi River Bridge resulted in a 68 percent reduction in winter season crashes and a benefit-to-cost ratio of 3.4:1.	Minnesota
	RITA ITS Benefits Database[37]	Reduced accidents in U.S 12 by 83 percent compared to years before the start of the pilot program.	Idaho

Source: RITA ITS Benefits Database, FHWA Reference Documents

---

[32] Best Practices for Road Weather Management, Version 3.0 (FHWA-HOP-12-046). June 2012. http://www.ops.fhwa.dot.gov/publications/fhwahop12046/fhwahop12046.pdf

[33] ITS JPO Benefits Database: http://www.itsbenefits.its.dot.gov/ITS/benecost.nsf/ID/101AF01585DAB4AF852573E100493B55

[34] ITS JPO Benefits Database: http://www.itsbenefits.its.dot.gov/ITS/benecost.nsf/ID/D94BFA1A43B5DA05852573DF00570EE7

[35] Seasons of Achievement: Accomplishments of the Road Weather Management Program (FHWA-JPO-10-004) http://ntl.bts.gov/lib/33000/33100/33152/seasons_pdf.pdf

[36] ITS JPO Benefits Database: http://www.itsbenefits.its.dot.gov/ITS/benecost.nsf/ID/D62EA78D6DF2E084852573E000711C1F

[37] ITS JPO Benefits Database: http://www.itsbenefits.its.dot.gov/ITS/benecost.nsf/ID/443E420C4C15E1068525733A006D4A20

PM-19. Reduction in the Extent of Capacity Losses and Delays Due to Fog, Snow, and Ice Events Including Freight

Inclement weather (snow, ice, and fog) is estimated to cause fifteen (15) percent of congestion[38] and twenty-three (23) percent of non-recurrent delay across the country. This results in an annual delay of 544 million vehicle-hours.[39] In addition, capacity losses are likely to occur due to snow accumulation and flooding as well as hazardous conditions such as high winds. Studies evaluating freeway traffic flow during weather events show that weather events impact free flow speed, speed at capacity and capacity at varying intensities. Negative impacts for free flow speed ranged from a minimum of two (2) percent (during light rain) to a maximum of sixty-four (64) percent (during snow). Capacity reductions ranged from four (4) percent (during light rain) to thirty (30) percent (during heavy rain). Findings are shown in Table 4-10 below.

Table 4-10. Freeway Traffic Flow Reductions Due to Weather

Weather Conditions	Average Speed	Free-Flow Speed	Volume	Capacity
Light Rain/Snow	3% - 13%	2% - 13%	5% - 10%	4% - 11%
Heavy Rain	3% - 16%	6% - 17%	14%	10% - 30%
Heavy Snow	5% - 40%	5% - 64%	30% - 44%	12% - 27%
Low Visibility	10% - 12%	N/A	N/A	12%

Source: FHWA RWMP Website

While national numbers for freight delays due to weather events are not readily available, data indicate that the estimated cost of weather-related delay to trucking companies ranges from 2.2 billion dollars to 3.5 billion dollars annually.[40]

Directly reducing the delays experienced by travelers driving in inclement weather conditions is one of the key elements of system performance improvement targeted by RWMP. The data for this measure are a compilation of benefits reported in various evaluations in the RITA ITS Benefits Database.[41] The database reports RWMP best practices implemented by State DOTs resulting in reductions in capacity loss and delays associated with adverse weather. Table 4-11 below shows the impacts of several of these strategies on traffic flow.

---

[38] "Operations Story" Federal Highway Administration, Office of Operations. 3 April 2013. http://www.ops.fhwa.dot.gov/aboutus/opstory.htm

[39] "How do Weather Events Impact Roads?" FHWA Road Weather Management Program. 31 Aug 2013. http://www.ops.fhwa.dot.gov/weather/q1_roadimpact.htm.

[40] "How do Weather Events Impact Roads?" FHWA Road Weather Management Program. 31 Aug 2013. http://www.ops.fhwa.dot.gov/weather/q1_roadimpact.htm.

[41] US DOT Research and Innovative Technology Administration (RITA) Intelligent Transportation Systems Joint Program Office (ITS JPO). "Knowledge Resources – Benefits Database." http://www.itsbenefits.its.dot.gov/

Table 4-11. Traffic Flow Impacts due to RWMP Identified Best Practice Technologies and Techniques

Strategies	Traffic Flow Impacts	Reporting State
Low Visibility Warning Systems	More uniform traffic flow reduced speed variability by 22 percent speeds increased 11 percent.[42]	Salt Lake City, Utah
Highway Advisory Radio	1/3 of Commercial Vehicle Operators (CVOs) reported (when interviewed) that they would change routes based on road weather information provided.[43]	Washington
High Wind Warning System	90 percent of motorists surveyed indicated they would slow down in response to messages displayed.[44]	Oregon
Road Weather Information Systems and Highway Advisory Radio	56 percent agreed the information helped them avoid travel delays.[45]	Washington
Weather Related Signal Timing	Reduced vehicle delay by 8 percent and vehicle stops by over 5 percent.[46]	Minneapolis/St. Paul
En-Route Weather Alerts and Pavement Condition Information	Average vehicle speeds decreased by 23 percent when traffic managers displayed condition data during high winds (i.e., wind speeds over 20 mph).[47] Average speeds were 12 percent lower when the system was activated during high wind events occurring simultaneously with moderate to heavy precipitation.[48] Average speeds declined by 35 percent when warnings were displayed on the signs when the pavement was snow-covered and wind speeds were high.[49]	Idaho
	In light rain condition, the 85th percentile speed decreased by 8 percent and speed variance was reduced from 6.7 mph to 5.7 mph.[50] During heavy rain, the 85th percentile decreased by 20 percent and speed variance was reduced from 6.1 to 5.6 mph.[51]	Florida

Source: RITA ITS Benefits Database

42 ITS JPO Benefits Database: http://www.itsbenefits.its.dot.gov/ITS/benecost.nsf/ID/9BE7AA0D428509D085256FCD0062E4AC

43 ITS JPO Benefits Database: http://www.benefitcost.its.dot.gov/ITS/benecost.nsf/ID/E4A9A7E1A7CC5D9A8525733A006D5D2B

44 ITS JPO Benefits Database: http://www.itsbenefits.its.dot.gov/its/benecost.nsf/SummID/B2008-00523

45 ITS JPO Benefits Database: http://www.itsbenefits.its.dot.gov/its/benecost.nsf/0/23B45777DB4FE98085256EA6004E86C3

46 ITS JPO Benefits Database: http://www.itsbenefits.its.dot.gov/its/benecost.nsf/ID/865389BFF80D8B4785256AE30059BE9F

47 Best Practices for Road Weather Management: Idaho DOT Motorists Warning System. Federal Highway Administration and Mitretek Systems. http://www.ops.fhwa.dot.gov/weather/Publications/Case%20Studies/08.pdf

48 Ibid.

49 Ibid.

50 Best Practice for Road Weather Management: Florida DOT Motorists Warning System. Federal Highway Administration and Mitretek Systems. http://ops.fhwa.dot.gov/weather/Publications/Case%20Studies/05.pdf

51 Ibid.

PM-20. Increase in Travel Time Reliability or Decrease in Variability Due to Road Weather Management Strategies during Adverse Weather Scenarios

Reliability is a measure of how travel time varies over time. Higher variations of travel time imply a lower level of reliability. Travel time reliability is often more important to travelers than average travel times. However, while the concept of reliability is intuitively understood by both travelers and policy-makers, the appropriate measures to calculate and communicate reliability continue to be a challenge. Most of the current reliability measures available today emerge from the frequency distribution of the travel times gathered over a specific period (Figure 4-23).

Source: Adapted from SHRP2 Project L05, Presentation to SHRP2 L38 Information Session, Cambridge Systematics, August 2012

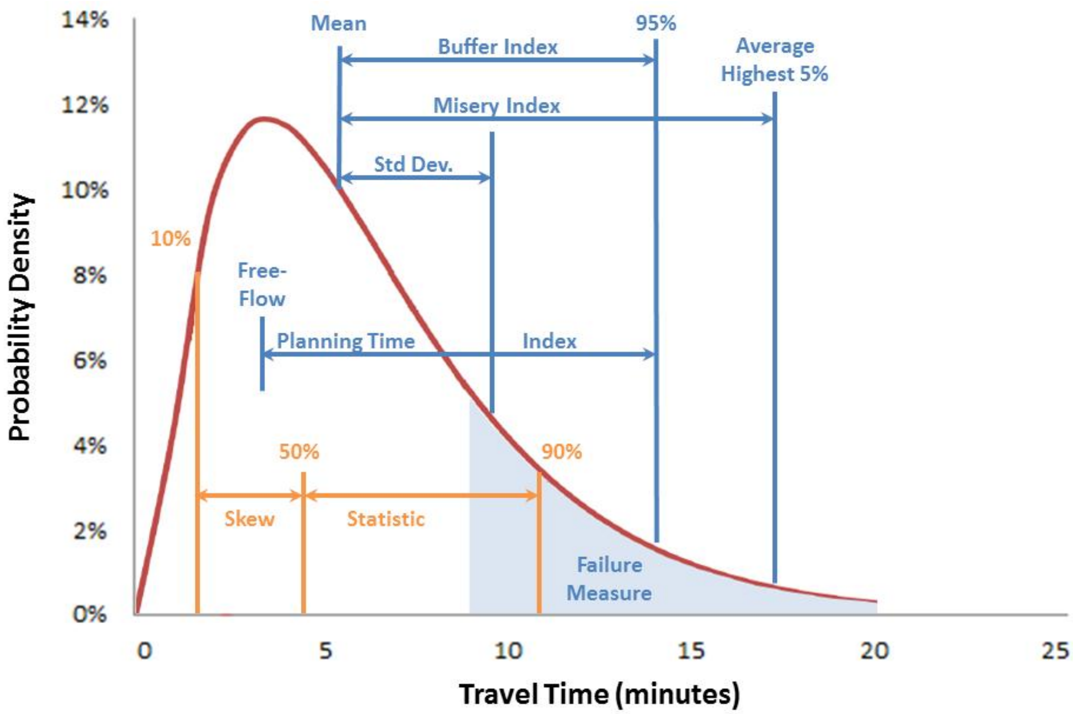


Figure 4-23. Reliability Measures Emerging from the Distribution of Travel Times

The degradation of reliability can be associated with the following seven causes of non-recurring congestion:

- Incidents
- Weather
- Work Zones
- Fluctuation in Demand
- Special Events
- Traffic Control Devices
- Inadequate Base Capacity.

Each of these causes can result in travel time variations from the normal. While these seven factors have been identified, they are not mutually exclusive. Weather, for example affects capacity and demand, as well as the probability of incidents. The impact on reliability is also dependent on a combination of factors or scenarios. For example, an ongoing weather event which occurs at rush hour (high demand) is different from a weather event which occurs during low-demand conditions. While the total variability is important, for many agencies, understanding the contribution of individual cause is crucial in developing mitigation approaches.

The second SHRP2 has included reliability as one of its key research focus areas. Its central goal is to reduce non-recurring congestion and improve travel time reliability through incident reduction, management, response, and mitigation. Among the research themes under the reliability focus area, the “Data, Metrics, Analysis and Decision Support” theme includes the development of performance measures to evaluate the effectiveness of actions to control and mitigate non-recurring congestion. Performance measurement related research projects include:

- Establishing Monitoring Programs for Travel Time Reliability and Monitoring;
- Analytic Procedures for Determining the Impacts of Reliability Mitigation Strategies; and
- Incorporating Reliability Performance Measures into Transportation.

These SHRP2 research projects focus on identifying, developing, and utilizing performance measures of travel time reliability based on archival and real-time data. These measures can be used for transportation planning, programming, project development, and operations. They can also be used to produce estimates of travel patterns as well as manage transportation networks in real-time.

Specifically, for RWMP performance evaluation, isolating the impacts of weather on travel time reliability is important. There are however not many examples where the role of weather and travel time reliability has been explored. In a paper submitted to TRB, researchers tried to quantify the impact of adverse weather on travel time variability on freeway corridors[52] reporting that on average, adverse weather results in twice the travel time variability compared with that under normal weather conditions. It is also found that rain has little or no effect on travel time variability below a certain critical inflow, but progressively impacts travel time variability above it. SHRP L02 – Establishing monitoring programs for travel time reliability describes approaches to identify the sources of unreliability as part of the travel time monitoring systems including a tagging approach to link observed travel times with non-recurrent event data (such as weather data from ESS or Automated Surface Observing Systems [ASOS]/Automated Weather Observing System [AWOS] stations) allowing for travel time distributions to be disaggregated across various combinations of congestion and non-recurrent condition.

Currently, SHRP2 programs are transitioning to implementation. Very few agencies track reliability measures, and even the ones that do, do not distinguish between the various causes of reliability. FHWA tracks reliability through the travel time index and the planning time index as part of the urban congestion reports at national or city-levels[53]. However, the information available is not at a level that can be used for assessing the performance of the RWMP products, activities, and services.

---

[52] Tu et al, The Impact of Adverse Weather on Travel Time Variability of Freeway Corridors, 86th meeting of the Transportation Research Board, 21-25, January 2007.

[53] “Urban Congestion Reports.” Federal Highway Administration (FHWA). April 26, 2013. http://ops.fhwa.dot.gov/perf_measurement/ucr/

Another research project commissioned by RITA[54] analyzed the impact of weather events on travel time reliability on Indiana Interstates. In this study, weather impact was evaluated by collecting travel time data during a snow event and comparing it to data obtained during normal weather conditions. Research findings indicate that travel time variance is significantly different under adverse versus normal weather conditions. Additionally, findings showed that the effects of the snow fall can persist for several hours after the now has stopped falling if the roadway is not cleared. Differences in travel time variability are shown in Figure 4-24.

Source: Analysis of Travel Time Reliability on Indiana Interstates

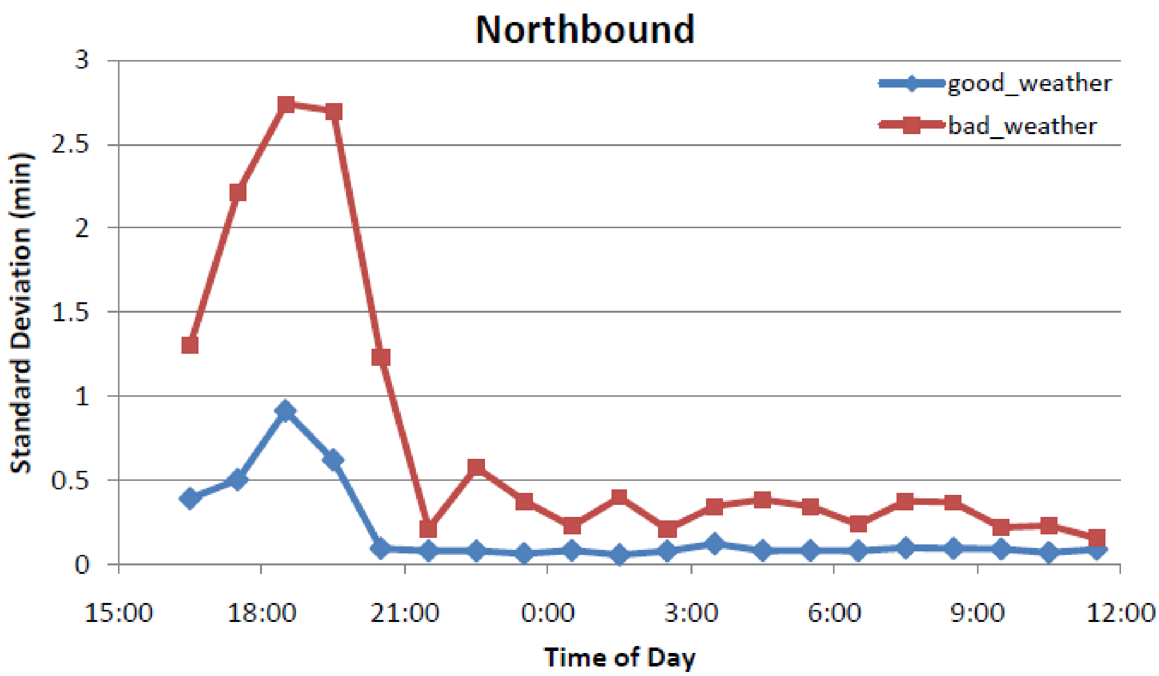


Figure 4-24. Variability in Travel Time for Snow Conditions and Regular Day

[54] Martchouk Maria and Mannering Fred. Nextrans Project No. 014PY01 Analysis of Travel Time Reliability on Indiana Interstates: USDOT Region V Regional University Transportation Center Final Report. 15 October 2009. http://www.purdue.edu/discoverypark/nextrans/assets/pdfs/completedprojects/Final%20Report%20014.pdf

Ultimately, reliability improvements take the form of better information and advisories for the travelers, as well as control strategies to account for the weather impacts. Examples of travel time reliability improvements due to weather related traffic management strategies are shown in Table 4-12.

Table 4-12. Impacts to Travel Time Reliability due to RWMP Identified Best Practice Technologies/Techniques

Strategies	Travel Time Reliability Impacts	Reporting State
Pre-Trip Road Condition Information and Forecast Systems	*Road-Weather Integrated Data System (RWIDS)*: 80 percent of motorists (responding to online survey) who used RWIDS indicated that the information they received made them better prepared for road-weather conditions.[55]	Idaho
	ESS Information on WSDOT Website: 94 percent of travelers (responding to online survey) indicated that a road weather information website made them better prepared to travel.[56]	Washington
Highway Advisory Radio (HAR)	*Road and Weather Restriction Broadcasts*: 1/3 of Commercial Vehicle Operators reported (when interviewed) that they would change routes based on road weather information provided.[57]	Washington
Fog Warning System	*Adverse Visibility Information System Evaluation (ADVISE)*: Reduced the average standard deviation of speed between vehicles by 22 percent. Prior to deployment, the standard deviation was 9.5 mph. After the system was deployed it decreased to 7.4 mph.[58]	Utah

Source: RITA ITS Benefits Database

[55] ITS JPO Benefits Database: http://www.itslessons.its.dot.gov/ITS/benecost.nsf/ID/24C5B3367FBC93EC852573DE004732C9

[56] ITS JPO Benefits Database: http://www.benefitcost.its.dot.gov/ITS/benecost.nsf/ID/23B45777DB4FE98085256EA6004E86C3

[57] ITS JPO Benefits Database: http://www.benefitcost.its.dot.gov/ITS/benecost.nsf/ID/E4A9A7E1A7CC5D9A8525733A006D5D2B

[58] ITS JPO Benefits Database: http://www.itsbenefits.its.dot.gov/its/benecost.nsf/ID/9BE7AA0D428509D085256FCD0062E4AC

PM-21. Reduction in Number of Tons of Salt or Chemical Usage in the U.S. Normalized by Winter Severity Index

This measure focuses on the tons of sodium chloride (aka "salt") used for winter maintenance activities as it relates to the environmental impacts and sustainability of maintenance operations. Salt is considered to be the most commonly used and economical deicer. According to the USGS, salt used for highway deicing has been linked to corrosion of bridge decks, motor vehicles, reinforcement bar and wire, and unprotected steel structures used in road construction. In addition, surface runoff, vehicle spraying, and windblown actions have been found to affect soil, roadside vegetation, and local surface water and groundwater supplies.[59]

It is estimated that seventy (70) percent of roadways within the United States are in areas that minimally receive five (5) inches of snow annually.[60] Table 4-13 below provides annual salt usage during inclement weather – for ice control and road stabilization – from 2006 through 2011.

Table 4-13. National Salt Consumption for Road Deicing

Year	Percentage of Total Salt Use[61]	Total Tons Used (millions)	Change in Consumption from Previous Year
2006[62]	29%	12.4	-
2007[63]	39%	20.8	68%
2008[64]	43%	22.6	09%
2009[65]	38%	16.9	(25%)
2010[66]	38%	18.7	11%
2011[67]	41%	19.6	05%

Source: United States Geological Survey Minerals Yearbook: Salt (2006 – 2011)

[59] http://minerals.usgs.gov/minerals/pubs/commodity/salt/myb1-2009-salt.pdf

[60] Houska, Catherine. Deicing Salt – Recognizing the Corrosion Threat. http://www.imoa.info/_files/pdf/DeicingSalt.pdf

[61] Total salt use includes the following uses as defined by USGS: chemicals, ice control, distributors, agricultural, food processing, general industrial, other uses and exports, and primary water treatment.

[62] http://minerals.usgs.gov/minerals/pubs/commodity/salt/myb1-2006-salt.pdf

[63] http://minerals.usgs.gov/minerals/pubs/commodity/salt/myb1-2007-salt.pdf

[64] http://minerals.usgs.gov/minerals/pubs/commodity/salt/myb1-2008-salt.pdf

[65] http://minerals.usgs.gov/minerals/pubs/commodity/salt/myb1-2009-salt.pdf

[66] http://minerals.usgs.gov/minerals/pubs/commodity/salt/myb1-2010-salt.pdf

[67] http://minerals.usgs.gov/minerals/pubs/commodity/salt/myb1-2011-salt.pdf

While national numbers for salt use are available, normalizing salt use by State for evaluation purposes is a challenge. Variability in winter weather severity and in levels of service—from year to year and from place to place—makes performance measurement difficult. Recently, the use of a Winter Weather Severity Index (WSI) has gained recognition as a way to gauge the relative severity of winter weather across various time frames or geographic regions. The correlation between salt usage and WSI can determine the efficiency of snow and ice operations in terms of material usage and cost in comparison to winter severity. In an evaluation of MassDOT's Snow and Ice Control Program,[68] annual salt usage was found to be highly correlated to WSI values over a ten year period. MassDOT also found that WSI values were a useful tool in evaluating performance in salt reduction. However, WSI factors vary from State to State as shown in Table 4-14 below. This variation makes it very difficult to evaluate salt usage since an "apples-to-apples" comparison cannot be made.

Table 4-14. Examples of State Winter Severity Indices and Salt Use

State	Winter Severity Index Factors	WSI Description
Washington State[69]	• Frost index (FI) – which is a severity index less the snowfall factor.	• Washington State DOT plans to use the FI when an overrun occurs in the snow and ice budget.
Wisconsin[70,71]	• Number of snow events. • Number of freezing rain events. • Total snow amount. • Total storm duration. • Total number of incidents (drifting, cleanup, frost runs).	• Seasonal Analysis. Goal of winter index is to relate winter severity to resource use. (Used to evaluate counties' performances and expenditures). • In 2011, the Statewide average WSI was 38.5 which is 20 percent higher than the average of the previous ten winters (31.9). Statewide, salt use increased 40 percent from the previous winter, driving total salt expenditures up 35 percent.
Idaho[72]	• Wind speed. • Surface precipitation water layer. • Pavement temperature.	• Storm-by-Storm Analysis. Relates the amount of time that ice exists on the road to the severity of a storm.

[69] Transportation Research Circular (Number E-C063): Sixth International Symposium on Snow Removal and Ice Control Technology. June 2004. http://onlinepubs.trb.org/onlinepubs/circulars/ec063.pdf

[70] Wisconsin DOT, *Winter Maintenance at a Glance, 2010 – 2011, Meeting Challenges with Best Practices.* http://www.dot.wi.gov/travel/road/docs/winter-maint-report.pdf

[71] Transportation Research Circular (Number E-C063): Sixth International Symposium on Snow Removal and Ice Control Technology. June 2004. http://onlinepubs.trb.org/onlinepubs/circulars/ec063.pdf

[72] Ibid.

Table 4-14. Examples of State Winter Severity Indices and Salt Use (Continued)

State	Winter Severity Index Factors	WSI Description
Minnesota[73]	• Number of snow events. • Number of freezing rain events. • Total snow amount. • Total snow duration.	• Seasonal Analysis. At the end of the season each district reports on factors which are used to calculate a single relative number for each district and a Statewide average. • Salt use during 2010 – 2011 winter mirrored 2005-2006, but the 2010-2011 severity index was 25 percent higher.
Massachusetts[74]	• Daily minimum temperatures. • Daily maximum temperatures. • Daily snowfall. • Number of snowfall events per month.	• MassDOT plans to expand winter efficiency measures going forward. Statewide salt usage from 2001-2010 adjusted for WSI will be used as basis for evaluating the performance measures. • MassDOT recently adopted this approach to evaluate whether newer application methods and equipment that were fully implemented Statewide in the winter of 2011 resulted in less salt being applied as compared to previous application methods. The State DOT used 440,000 tons of salt during the 2011-12 winter season while in 2010-11 it used 926,000 tons.
New Hampshire[75]	• High/low temperatures. • Snowfall amount. • Computed on a monthly basis for the months of November, December, January, February and March.	• Used a Winter Severity Index developed and published in Washington State University's report NCHRP H-350. • NHDOT recently started using this method. Data collected by NHDOT for a 10 year period shows an 85-92 percent correlation between salt usage and WSI values. The correlation model is used to compare existing application methods with newer methods for reduced material usage and operation cost.

Source: Winter Maintenance Reports

[73] Minnesota DOT, *2010–2011 Annual Winter Maintenance Report At a Glance.* http://www.dot.state.mn.us/maintenance/docs/MnDOT%20Winter%20at%20a%20Glance_1.26.12_WEB.pdf

[74] MassDOT Snow & Ice Control Program ;2012 Environmental Status and Planning Report EOEA#11202, http://www.mhd.state.ma.us/downloads/projDev/ESPR_2012/EnvironStatus_PlanningRpt_0212.pdf

[75] New Hampshire DOT. "Effective Resource Management – 2011." http://www.nh.gov/dot/org/commissioner/balanced-scorecard/department/documents/bs_performance_salt_usage.pdf

In addition to the examples above, other States are currently developing methodologies for using WSIs. For example, Utah is conducting a two-phase research study to create a State Winter Severity Index.[76] The first phase was a review of existing research findings for rating systems used in other States. Results can be found in the *Utah Winter Severity Index, Phase 1: Report No. UT-12.12.*[77] The second phase is to develop a model specific to Utah. Table 4-15 provides examples of salt usage by State along with its corresponding WSI.

Table 4-15. Examples of Salt Usage by State

State	Year	Snowfall Range* (inches)	Salt Used (tons)	Average Statewide Winter Severity Index
Minnesota[78]	2009 - 2010	30 - 53	180,252	44.8
	2010 - 2011	67 - 89	267,860	57.1
Wisconsin[79]	2009 - 2010	23 - 204	408,523	26.6
	2010 - 2011	63 - 273	573,253	38.5
Massachusetts[80]	FY10	No data reported	367,436	10.9
	FY11	No data reported	556,839	27.2

*Minnesota and Wisconsin snowfall range sourced from DOTs. Massachusetts snowfall range sourced from the National Climatic Data Center, sensor station data.

Source: State DOTs, National Climactic Data Center.

Reducing salt used and switching to other alternative deicers or anti-icing methods is an important strategy of many agencies, not only for saving maintenance cost but also reducing negative environmental effects, because salt is highly soluble and elevates the levels of sodium and chloride in soil and water.

Through the implementation of road weather management tools like MDSS and treatment technology such as deicing, anti-icing methods can help agencies optimize their usage of materials, thereby providing safe mobility while reducing the amount of salt on the highways. Best practices for decreasing salt usage through RWMP technologies and techniques are provided in Table 4-16.

[76] Utah Department of Transportation. "Research Newsletter." Winter 2013. http://www.udot.utah.gov/main/uconowner.gf?n=3089208307814990

[77] Utah Winter Severity Index Phase I (Report No. UT-12.12) UDOT Weather Operations. June 2012. http://www.udot.utah.gov/main/uconowner.gf?n=11539601019505676

[78] 2010 – 2011 Annual Winter Maintenance Report At a Glance. Minnesota Department of Transportation. http://www.dot.state.mn.us/maintenance/docs/MnDOT%20Winter%20at%20a%20Glance_1.26.12_WEB.pdf

[79] 2010 – 2011 Winter Maintenance at a Glance: Meeting Challenges with Best Practices. Wisconsin Department of Transportation. http://www.dot.wi.gov/travel/road/docs/winter-maint-report.pdf

[80] MassDOT Snow & Ice Control Program ;2012 Environmental Status and Planning Report EOEA#11202, http://www.mhd.state.ma.us/downloads/projDev/ESPR_2012/EnvironStatus_PlanningRpt_0212.pdf

Table 4-16. Decrease Salt Usage due to RWMP-Identified Best Practice Technologies/Techniques

Strategy	Reduction	Reporting State
Maintenance Decision Support System (MDSS)	2008-2009 Snow and Ice Season: Implementation of MDSS resulted in Statewide savings of $9,978,536 (188,274 tons) in salt usage and $979,136 (41,967 hours) in overtime compensation from the previous winter season.[81]	Indiana
RWIS (used for snow and ice control)	Installation of 9 RWIS stations resulted in a first year savings of $39,000 on salt and sand. The Massachusetts Highway Administration (MHA) estimated that a complete RWIS in Boston could save up to $250,000 annually.[82]	Massachusetts
	Installation of RWIS on bridge over the James River recovered 96 percent of equipment and installation costs over a single mild winter by avoiding unnecessary deicer application.[83]	Virginia
Anti-icing	Results in a 10-30 percent reduction in materials used.[84]	Minnesota
	Led to an overall cost savings of 52 percent.[85]	Colorado
	Resulted in a cost savings of 75 percent for freezing rain events.[86]	Oregon
	Since starting anti-icing techniques, there has been 15-25 percent less salt usage (when normalized for winter severity).[87]	Wisconsin

[81] ITS JPO Benefits Database: http://www.itsbenefits.its.dot.gov/ITS/benecost.nsf/ID/A7FE4E582135C9A085257718005F1A21

[82] US Environmental Protection Agency (US EPA). "Source Water Protection Practices Bulletin: Managing Highway Deicing to Prevent Contamination of Drinking Water."

[83] US Environmental Protection Agency (US EPA). "Source Water Protection Practices Bulletin: Managing Highway Deicing to Prevent Contamination of Drinking Water."

[84] Western Transportation Institute and Montana State University. Cost Benefits of Weather Information for Winter Road Maintenance, Final Report, April 2009.

[85] Ibid.

[86] Ibid.

[87] Ibid.

Table 4-16. Decrease Salt Usage due to RWMP-Identified Best Practice Technologies/Techniques (Continued)

Strategy	Reduction	Reporting State
Pre-wetting	Results in an up to 30 percent reduction in materials used.[88]	Minnesota
	Treated salt/pre-wetting allows for a 20 percent reduction in salt application rates.[89]	New York
	Pre-wetting salt with an M-50 product reduced salt usage by 35-40 percent.[90]	Nebraska
	Increased use of efficiency measures, including pre-wetting, led to a reduction in annual Statewide salt usage in 2010/11. Usage was approximately 170,000 tons (23 percent) less than that used in the winters of 2003 and 2005, (both of which had similar WSI values than 2011).[91]	Mass DOT

Source: RITA ITS Benefits Database, Research Reports.

Best management practices (BMPs) can also reduce the negative environmental impacts of road salt without compromising public safety. Many States and municipalities are introducing regulations with an aim to control the use of salt and other chemicals that are harmful for water and plants, and also reduce the salt-related corrosion on cars, equipment, roads and bridges. BMPs include investing and calibrating equipment for precise application and providing worker training. In addition to the environmental benefits, implementing BMPs is fiscally prudent, as it requires less spending on deicing materials, equipment, and labor, as well as the indirect costs due to salt-related corrosion of roads, bridges, vehicles, and other infrastructure. For instance, Colorado reported that implementing anti-icing reduced the total annual cost of winter operations from $5,200 per lane mile to $2,500 per lane mile.

[88] Western Transportation Institute and Montana State University. Cost Benefits of Weather Information for Winter Road Maintenance, Final Report, April 2009.

[89] Ibid.

[90] ITS JPO Benefits Database: http://www.benefitcost.its.dot.gov/ITS/benecost.nsf/ID/49595B76A63247BD852573DE005EDAAA

[91] MassDOT Snow & Ice Control Program ;2012 Environmental Status and Planning Report EOEA#11202, http://www.mhd.state.ma.us/downloads/projDev/ESPR_2012/EnvironStatus_PlanningRpt_0212.pdf

Summary of Performance across the Objective

An increasing number of case studies point to progress in using best practices for achieving safety, mobility, and productivity goals around the country. Since RWMP is not an operating or a rule-making agency, the primary pathway to influence overall system performance is to encourage the adoption of best practices and support robust evaluations of the same. Experiences like Indiana DOT's use of MDSS or the safety benefits offered by low-visibility warning systems are proof that these systems work and have the desired impacts. Aggressive management of salt use, not only from a cost-saving standpoint but also from an environmental sustainability viewpoint, is starting to emerge as a priority at State levels but consistent approaches to measure and evaluate their performance longitudinally across winters are rare.

Objective 7: Engage the Climate Change Community in Transportation Maintenance and Operations

Adaptation to climate change is a topic of recent and great interest in the transportation community. The US DOT Policy Statement on climate change adaptation[92] states the following:

> *The United States Department of Transportation (DOT) shall integrate consideration of climate change impacts and adaptation into the planning, operations, policies, and programs of DOT in order to ensure that taxpayer resources are invested wisely and that transportation infrastructure, services and operations remain effective in current and future climate conditions. The climate is changing and the transportation sector needs to prepare for its impacts. Through climate change adaptation efforts, the transportation sector can adjust to future changes, minimize negative effects and take advantage of new opportunities.*

FHWA' s Sustainable Transport and Climate Change Team, under the Office of Planning, Environment, and Realty, Office of Natural and Human Environment has been identifying climate change issues faced by State DOTs and Metropolitan Planning Organizations (MPOs), conducting workshops and peer exchanges on this topic and developing guidelines and tools to address their concerns. The USDOT Climate Change Clearinghouse[93] is another important source of information on issues faced by agencies related to climate change. In June 2011, TRB published a research circular[94] assessing the state-of-the-practice of adaptation strategies being considered by transportation agencies. All of these resources provide an emerging picture of the changes required at an agency level to address the challenges posed by climate change.

The challenges posed by climate change to infrastructure design and long-term land-use planning are more easily described than how an agency needs to adapt their day to day operations strategy given the varied nature of evolving climate and travelers' responses to changing climate. A recent white

[92] U.S. Department of Transportation (USDOT), 2011: Policy Statement on Climate Change Adaptation. Washington, DC, USA. Accessed 4 Sept 2012. http://www.fhwa.dot.gov/environment/climate_change/adaptation/policy_and_guidance/usdotpolicy.pdf

[93] U.S. Department of Transportation (USDOT), 2012: Transportation and Climate Change Clearinghouse. Washington, DC, USA. Accessed 4 Sept 2012 <http://climate.dot.gov>.

[94] Transportation Research Board (TRB), 2011: Adapting Transportation to the Impacts of Climate Change: State-of-the-Practice 2011. Transportation Research Circular E-C152. Washington, DC, USA.

paper prepared for FHWA summarized these impacts and the role of systems management and operations as part of climate change adaptation[95]. The climate change effects can be separated into two general categories based on whether the effect is part of a climate trend (e.g., increasing annual average air temperatures) or is associated with a distinct climate event (e.g., storm, flood, drought, heat wave), as these different categories of effects will necessitate different types of operational responses by transportation agencies. Road weather management, as an operational strategy, is obviously a core component of the adaptation strategy related to climate events. As the frequency, severity and the probability of occurrence at particular locations change, a robust RWMP is essential. Less obvious however are the system maintenance and operations policies and actions associated with climate trends which affect how agencies budget and staff their road weather management activities.

This is an emerging area for the RWMP. Recent activities have:

- Helped define the Operations and Maintenance measures in INVEST, particularly with respect to snow and ice control. INVEST is the online tool, developed by FHWA to incorporate sustainability principles into the transportation system.
- Promoted through the RWMP the concepts of sustainability within the maintenance community, especially with respect to snow and ice control.
- Worked with the climate community to better understand the potential impacts of climate change on Operations & Maintenance, to determine knowledge gaps, to identify R&D needs, and to explore how climate change could be incorporated into O&M practices.
- Supported a national, multi-disciplinary effort led by OSTP & NOAA to determine weather observing needs for the transportation community.

Performance measures continue to be refined in this area. Currently, the following performance measure describes the role that road weather management plays in climate change adaptation and sustainability.

PM-22. Number of Public Agencies Meeting “INVEST” and/or Sustainability Criteria Related to Road Weather Management

FHWA's INVEST is designed to provide information and techniques to help agencies integrate sustainability best practices into their projects and programs. INVEST is intended to provide guidance for practitioners to evaluate the sustainability of their transportation projects and programs and to encourage sustainability progress within the field of transportation. It is not required, and it is not intended to encourage comparisons between transportation agencies. Agencies may use INVEST as a way to identify best practices in roadway sustainability, communicate with stakeholders and decision makers about sustainability, and develop methods for conducting self-assessments and prioritizing areas for improvement. Specifically, for this performance measure, INVEST has criteria that agencies can score themselves against to track progress along sustainability and climate change initiatives. A subjective assessment of the road weather community against these criteria is provided in Table 4-17. The assessment is based on the data collected for all the previously described performance measures.

[95] Planning for Systems Management & Operations as part of Climate Change Adaptation, White Paper to FHWA, produced by Battelle, March 2013.

Table 4-17. INVEST Scoring Requirements for Road Weather Management Programs and RWMP Performance Measurement 2012 Update Assessment

INVEST OM-12: Road Weather Management Program (Score: 1 – 15 pts.)		Assessment of Current Nationwide Conditions
Criteria[96]	**Description**[97]	
Develop a Road Weather Management Program **(2 pts.)**	An RWMP includes strategies that can be used to mitigate the impacts of rain, snow, ice, fog, high winds, flooding, tornadoes, hurricanes, avalanches, and other inclement weather on traffic. The RWMP will vary in size and scope depending on the needs of the agency. It could be a combination of multiple documents that cover management of different conditions or different regions, or could be a single, consolidated document. For the purposes of evaluating this criterion, the agency should consider all applicable materials and respond according per the majority of their practices.	High, especially in the northern-tier or the snow belt States.
Set Goals and Monitor Progress **(3 pts.)**	Scoring for this requirement is based on the following, cumulative elements. The first element must be accomplished to earn the second: • (2 pts.) Establish quantifiable performance metrics for the RWMP. Measures could be based on level of service, amount of materials used per event, and other relevant parameters. Measures could be qualitative and/or quantitative. • (Additional 1 pt.) Monitor progress towards goals for at least one year after goal establishment and show measurable advancement towards stated goals.	Sporadic across the nation. Surveys conducted as part of this study indicate that 44 percent of the northern tier State DOTs surveyed are neither using a winter severity index nor publishing winter maintenance performance measures. Six State DOTs (24 percent) report performance measures and calculate a severity index.

[96] Criterion Details: OM-12 Road Weather Management Program. INVEST. Federal Highway Administration. https://www.sustainablehighways.org/764/108/road-weather-management-program.html

[97] Ibid.

Table 4-17. INVEST Scoring Requirements for Road Weather Management Programs and RWMP Performance Measurement 2012 Update Assessment (Continued)

INVEST OM-12: Road Weather Management Program (Score: 1 – 15 pts.)		**Assessment of Current Nationwide Conditions**
Criteria[96]	**Description**[97]	
Implement a Road Weather Information Systems **(3 pts.)**	The agency implements an RWIS which measures the weather and road conditions using sensors on the side of the road to track weather and road conditions to plan and implement the appropriate treatment actions. The RWIS should provide timely information on prevailing and predicted conditions to both transportation managers and motorists (e.g., posting fog warnings on Changeable Message Signs and listing flooded routes on web sites). <u>One</u> of the following scores applies: • (0 pts.)The agency does not have an RWIS. • (1 pt.) The agency is testing an RWIS in only a few locations. • (2 pts.) The agency implements a RWIS in select areas identified, but has not implemented a system agency-wide. • (3 pts.) The agency implements a RWIS agency-wide in most or all areas identified vulnerable to weather conditions (e.g., mountain passes, high wind areas, bridges, etc.).	High. The *Clarus* System is a good indication of the level of use of RWIS around the country. Over 39 States not only have RWIS, they are connected to the national system.
Implement the Standards of Practice or Standard Operating Procedure (SOP) for Snow and Ice Control **(2 pts.)**	Scoring for this requirement is based on the following, cumulative elements. The first element must be accomplished to earn the second: • (1 pt.) Have an RWMP that includes, at a minimum, the following elements specific to snow and ice control: Reducing salt use in environmentally sensitive areas, Existence of an anti-icing program, Conducting periodical training program for proper use of salt and chemicals, Best Management Practice (BMP) for chemical storage facilities, Proper storage of chemical and chemical-abrasive stockpiles, and Proper calibration of equipment o Reducing cost and improving fuel efficiency by planning and optimizing routes. • (Additional 1 pt.) The agency's program includes performance standards that take into account sustainability, and demonstrate a reduction in materials and truck fuel usage.	Some best practices exist but are not uniform across the nation. Activities to encourage standards for snow and ice control are being supported by various pooled fund studies, AASHTO and the RWMP.

Table 4-17. INVEST Scoring Requirements for Road Weather Management Programs and RWMP Performance Measurement 2012 Update Assessment (Continued)

INVEST OM-12: Road Weather Management Program (Score: 1 – 15 pts.)		**Assessment of Current Nationwide Conditions**
Criteria[96]	**Description**[97]	
Implement Materials Management Plan **(2 pts.)**	Successful implementation of a Materials Management Plan to monitor quantities of salt applied and level of service (e.g., interstates bare and dry 1 hour after event) during and after an event; includes salt, chemicals (de-icing agents), sand, etc.	Same as previous
Implement a Maintenance Decision Support System **(3 pts.)**	Develop a MDSS to improve the effectiveness and efficiency of roadway weather treatments and implement best practices. The MDSS can be based on weather report monitoring or based on RWIS sensing technologies installed roadside or mounted on maintenance vehicles to measure and monitor the road conditions. One of the following scores applies: • (0 pts.) The agency does not have an MDSS. • (1 pt.) The agency has MDSS processes that are not based on roadside or vehicle mounted sensing technologies. • (2 pts.) The agency has MDSS processes that are based on either roadside or vehicle mounted sensing technologies. • (3 pts.) The agency has MDSS processes that are based on both roadside and vehicle mounted sensing technologies.	Almost three-quarters (74 percent) of the State DOTs responding to the 2013 survey said they either have in place (fully or partially deployed), are considering, or need an MDSS, and 26 percent reported that they don't need an MDSS

Source: FHWA INVEST Website, Battelle

Summary of Performance across the Objective

Overall, State DOTs, especially the northern-tier States, meet many if not all of the programmatic criteria identified in INVEST, such as having a road weather program, having RWIS and the use of MDSS. The major weaknesses pertain to performance measurement, use of SOPs and material management, which are more sporadic in their use across the nation.

Chapter 5 Assessing Overall Performance Advances

Evidence of progress across all seven objectives is clearly demonstrated through the twenty two performance measures. RWMP performance findings are summarized in Table 5-1 and the available data have been collected either in direct support of each measure or indirectly through one or more indicators that are linked to the measure. The data vary in their ability to support the measure, and some of the data available only offer weak or partial quantification of the measure. These issues have been discussed in detail in Chapter 4, and recommendations are made regarding future adjustments to the measures and indicators, as well as the need to identify new sources of data that can offer stronger support for the measures in Chapter 6.

Table 5-1. Summary of Overall Performance Advances

RWMP Objectives	Final 2012 Performance Measures	Highlights	Assessment of Performance Measures
Objective 1: Build Partnerships with Transportation and Weather Communities	PM-1: Number of agencies participating in road weather R&D projects	• Over 45 public agencies have participated in the *Clarus* System. • 8 State DOTs have conducted *Clarus* demonstrations while 7 State and local DOTs have participated in *Clarus* BAAs. • 14 public agencies have been involved in weather responsive traffic management including TMC weather integration, human factors, TrEPs, and WRTM implementation. • 3 State DOTs have been involved in integrated mobile observations/CV, 5 agencies with MDSS, and 4 State DOTs with the Western State Rural Transportation Consortium.	***Measure adequately captured*** • R&D activities cover all the major initiatives of the RWMP including *Clarus*, MDSS, WRTM, and Connected Vehicle-related research. • Data was gathered from interviews with RWMP personnel and review of the R&D program.
	PM-2: Number of agencies participating in and benefiting from Road Weather Management stakeholder meetings/workshops	• Available evaluations from workshops/meetings show very positive feedback from the attendees. • Demonstrated trend of increasing yearly levels of State participation in Stakeholder meetings (MDSS, *Clarus*, RWMP, and WRTM).	***Measure captured to extent possible given available data*** • From 2001 to 2003, focus of meetings was MDSS. From 2004-2009, both *Clarus* and MDSS were discussed. From 2010, focus was on broader RWMP activities. • In addition to State DOTs, various other private and public agencies attended the stakeholder meetings. Agencies are not included since detailed participation records are not available. • Data gathered from statistics maintained by the RWMP.
	PM-3: Number of Organizations/Groups where FHWA is Represented (National and International)	• In four self-reported cases RWMP has a leadership role in setting the agenda and strategic direction of the organization/group. • In nine self-reported cases it is a member of an organization/group. • Organizational participation is diverse including involvement in AASHTO subcommittees, TRB committees, ITS America, and the American Meteorological Society.	***Measure adequately captured*** • Participation data was provided by all RWMP staff and includes all organizational involvement across RMWP. • The data for this measure are gathered from interviews with RWMP personnel.

Table 5-1. Summary of Overall Performance Advances (Continued)

RWMP Objectives	Final 2012 Performance Measures	Highlights	Assessment of Performance Measures
Objective 2: Raise road weather management knowledge and capabilities across the transportation industry	PM-4: Number of public agencies and attendees who have taken any of the training courses sponsored by the RWMP	• Since the last performance measure update, in order to reach a larger audience, the information for some online training courses has been more widely publicized. • Courses have shown consistent or increased levels of participation since being offered.	***Measure adequately captured*** • Partnering with other agencies helps RWMP training courses to gain exposure during the development and implementation of these training activities. Partnerships include NHI, the Consortium for ITS Training and Education (CITE) and the Institute of Transportation Engineers (ITE). • Training course data includes instructor-led, web-based ("blended") courses and online, independent study courses.
	PM-5: Number of agencies and participants in road weather management webinars	• Since first webinar in 2006, the program has experienced consistently high participation levels. Between 2006 and 2009, four webinars hosted with 543 participants. In 2012 alone, four webinars held with 479 participants. This increase in participation shows a high level of interest in the webinars even after a two year lull.	***Measure adequately captured*** • Data made available through the data archive maintained by National Transportation Operations Coalition (NTOC).
	PM-6: Number of meetings, site visits or venues where road weather management presentations/briefings were made	• From 2009 to 2012, RWMP presented in every TRB Annual Meeting, AMS Annual Meetings, TRB-sponsored International Conference on Winter Maintenance and Surface Transportation Weather, Aurora, Clear Roads, ITS-Irvine, Connected Vehicle Pool Fund Study, ITS America 2012, and PIARC – Winter Maintenance Technical Committee. • Exact numbers on the measure are difficult to obtain given the diversity of engagements to which RWMP is invited to participate.	***Measure captured to extent possible given available data*** • Data made available through records kept by RWMP staff. • Ad-hoc requests supported by the program not captured in this measure.
	PM-7: Number of hits/visits to RWMP websites	• In 2012, 68 percent of evaluation survey respondents (conducted after annual stakeholder meeting) had visited the RWMP website. Of these respondents, 71 percent had downloaded material. These indicate a high degree of use and awareness of the website. • Summary statistics on usage over the April 2012 to March 2013 timeframe indicate an average monthly growth rate of the following: hits (14 percent), page views (9 percent), and visitors (5 percent).	***Measure captured to extent possible given available data*** • Of the identified road weather websites, (RWMP, ITS-JPO, *Clarus*), limited usage data was obtained only on the RWMP website.

Table 5-1. Summary of Overall Performance Advances (Continued)

RWMP Objectives	Final 2012 Performance Measures	Highlights	Assessment of Performance Measures
Objective 3: Advance the collection, processing & distribution of fixed and mobile road weather observations	PM-8: Number of transportation agencies participating in road weather data sharing activities	• 2006 to 2008 – number agencies contributing ESS increased from 3 to 33 with a total of 1,700 ESS reporting to the *Clarus* System. • 2008 to 2013 – number of agencies increased from 33 to 49 with a total of 2,437 ESS reporting to *Clarus*. • Results represent a 45 percent increase in the number of agencies and a 43 percent increase in the number of sensor stations in the four years since performance measurement.	***Measure adequately captured*** • RWMP and *Clarus* System records used to obtain data. • *Clarus* is transitioning to MADIS as well as being included in the Weather Data Exchange, a part of the Connected Vehicle research initiative. Tracking this measure in the future might include the participation of agencies in the MADIS program as well as the Weather Data Exchange.
	PM-9: Number of transportation agencies that subscribe to road weather products and services	• Access to most of the sources included in the survey has increased slightly or leveled off over the past six years. • 2013 Survey reveals high usage of road weather products (100 percent use NWS, 93 percent use their agency sensors, ~80 percent use private sector sources, 63 percent use national observation systems like *Clarus*. • The increased access to sources implies a widespread awareness of weather products and information sources along with the increasing relevance of these products in State transportation operations.	***Measure captured to extent possible given available data*** • Data collected through the ITS Deployment Statistics survey in 2004 and 2007, but comparable survey has not been conducted since. 2007 data supplemented in 2013 by an RWMP performance survey of State DOTs. • Data was derived from two different kinds of surveys with different sets of respondents; the results are not fully comparable.
	PM-10: Number of agencies collecting mobile observations of road weather data from vehicle fleets	• About quarter of DOTs said none of their vehicles collect data. • 3 out of 4 State DOTs are using road weather data collection strategies in some of their vehicles. • Potential for DOTs that are collecting some mobile data from some of their vehicles to increase that with a higher proportion of their vehicle fleets.	***Measure adequately captured*** • Data sourced from 2013 State DOT Survey. • Prior to the implementation of the 2013 State DOT survey, there were no publically available data sources to quantify this measure, as this is an emerging research area for the RWMP.
	PM-11: Number and distribution of fixed Environmental Sensor Stations (ESS)	• As of June 2008, there were an estimated 2,499 ESS of which 2,017 were part of a Road Weather Information System (RWIS). • As of 2012, agencies had connected 2,435 ESS to *Clarus*.	***Measure adequately captured*** • While the growth of ESS deployment is an important statistic, it can be misleading. Many States have already deployed ESS so number is not expected to increase substantially in coming years. Additionally, ESS might not be used in support of operations.

Table 5-1. Summary of Overall Performance Advances (Continued)

RWMP Objectives	Final 2012 Performance Measures	Highlights	Assessment of Performance Measures
Objective 4: Increase the use of weather-enabled decision-support tools and dynamic mobility applications	PM-12: Number of agencies adopting MDSS technologies and methods	• 2013 – Almost three-quarters of State DOTs said they either have in place, are considering, or need an MDSS with 26 percent reporting they don't need an MDSS. • 2008, five State agencies reported regular operational use of an MDSS system, 2013 – seven State DOTS reported use. • Results suggest that usage of MDSS technology has expanded over the past five years.	***Measure captured to extent possible given available data*** • Data sourced from 2013 State DOT Survey (survey did not cover all the States covered in 2008). • Given that nine State DOTs said they either use MDSS partially or are considering deployment, there is room for expansion in MDSS use.
	PM-13: Number of agencies using other weather-related decision-support tools	• Most State DOTs (96 percent) are offering traveler information to assist drivers, especially during weather events. • Majority of State DOTs are using more than one tool, with over three-quarters (77 percent) report using three or more of them. • Evidence suggests State DOTs are using a wider array of decision support tools now to support their road weather management practices, and the use of some of these tools is becoming increasingly widespread.	***Measure adequately captured*** • Data sourced from 2013 State DOT Survey.
	PM-14: Number of agencies using weather-responsive traffic-related analysis, modeling, simulation and decision-support tools	• Usage of Traffic analysis models and tools is very low among the responding State DOTs (83 percent). • Majority of DOTs report using no traffic models (86 percent). • A few of the respondents said they were unaware whether or not their State DOT was using any of these tools.	***Measure adequately captured*** • Data sourced from 2013 State DOT Survey. • Significant potential for more widespread use of these models and tools especially for weather-related applications.

Table 5-1. Summary of Overall Performance Advances (Continued)

RWMP Objectives	Final 2012 Performance Measures	Highlights	Assessment of Performance Measures
Objective 5: Develop and support operational deployment of advanced road weather management strategies	PM-15: Number of States disseminating advisory weather and road weather information to travelers	• 80 percent of agencies report road surface information on DMS at least in some locations within the State, 52 percent share weather information on Twitter, 50 percent share weather and road weather information on Highway Advisory Radio. • Current survey results show further progress since 2007 in the deployment of road weather information to the traveling public, though direct comparisons are difficult given differences in the surveys conducted in 2007 and 2013 and the response rates to these surveys.	***Measure captured to extent possible given available data*** • Source of 2004 and 2007 data is ITS Deployment Statistics Survey. • 2010 version of the ITS Deployment Survey did not include these questions. • Questions related to the provision of traveler information were posed in the 2013 survey of State DOTs.
	PM-16: Number of agencies using control and treatment strategies during weather events	• Traffic incident management practices in response to inclement weather are most widely deployed of all strategies surveyed (Close to 88 percent of agencies). • Adjusting signal timing at intersections in response to weather remains relatively rare (21 percent). • Use of technology for road closures (52 percent), temporary restrictions based on ESS (50 percent), varying speed limits (28 percent), and adjusting ramp meters (23 percent) are used by States in appropriate locations. • Results indicate substantial room for further adoption of these kinds of road weather operational strategies across the States.	***Measure captured to extent possible given available data*** • There was limited information available for this measure in 2007 through the ITS Deployment Statistics. This information is not available in 2010 either. • To obtain current information on State DOT use of control and treatment strategies during weather, six new questions were included in the 2013 survey.

Table 5-1. Summary of Overall Performance Advances (Continued)

RWMP Objectives	Final 2012 Performance Measures	Highlights	Assessment of Performance Measures
Objective 6: Improve overall system performance during weather events	PM-17: Reductions in agency costs of weather-related maintenance and operations activities	• Case studies showed that winter maintenance costs decreased as the use of weather information increased or its accuracy improved. • Use of MDSS is showing substantial benefits and reductions in costs. For example, Indiana reported a cost reduction (per winter) of $1.3 million (58,274 hours) in overtime and $ 12 million in salt. • Treatment actions such as anti-icing and pre-wetting have also demonstrated significant material and costs savings. • Overall, the number of positively evaluated MDSS systems continues to grow.	***Measure captured to extent possible given available data*** • Reported results from literature search and the RITA ITS Benefits Database. • At a summary level, the last three years have seen increased costs of winter maintenance nationally. However, these numbers are hard to attribute to RWMP performance and may be indicative of seasonal and geographic variation in weather and differences in road weather conditions and local practices.
	PM-18: Reduction in number and types of fatalities and crashes attributed to adverse weather nationally	• Low visibility and other active warning systems, as well as anti-icing have demonstrated significant benefits. For example, an automatic bridge anti-icing system in Utah reduced crashes by 64 percent. • Nationally, the number of fatal crashes occurring during inclement weather is generally on a decreasing trend similar to overall crashes (irrespective of the cause of incident). The rate of decrease however is slower for weather-related crashes compared to crashes as a whole.	***Measure captured to extent possible given available data*** • Reported results from literature search, RITA ITS Benefits Database, Fatality Analysis Report System (FARS), and FHWA Highway Statistics Reports. • It is still hard to determine the contribution of specific strategies on national crash rates that can be attributed to the RWMP.
	PM-19: Reduction in the extent of capacity losses and delays due to fog, snow, and ice events including freight	• Active warning systems and traveler information systems have demonstrated benefits on traffic flow. For example, a low visibility warning system in Salt Lake City, Utah reduced speed variability by 22 percent and increased speed by 11 percent.	***Measure captured to extent possible given available data*** • Data is a compilation of benefits reported in various evaluations in the RITA ITS Benefits Database. • National numbers for freight delays due to weather events are not readily available.
	PM-20: Increase in travel time reliability or decrease in variability due to road weather management strategies during adverse weather scenarios	• Some early reliability benefits of traveler information during weather conditions have been reported. For example, in Idaho, 80 percent of motorists (responding to a survey) who used the pre-trip road condition system indicated that the information they received made them better prepared for road-weather conditions. • SHRP2 and other efforts will increase the data available to quantify the measure.	***Measure captured to extent possible given available data*** • Reported results from literature search and RITA ITS Benefits Database. • Very few agencies track reliability measures, and even the ones that do, do not distinguish between the various causes of reliability.

Table 5-1. Summary of Overall Performance Advances (Continued)

RWMP Objectives	Final 2012 Performance Measures	Highlights	Assessment of Performance Measures
	PM-21: Reduction in number of tons of salt or chemical usage in the U.S. normalized by winter severity index	• Use of a Winter Weather Severity Index (WSI) has gained recognition as a way to gauge relative severity of winter weather across geographic regions. • Several States are currently developing methodologies for using WSIs. • Implementation of road weather management tools like MDSS and treatment technology such as deicing, anti-icing methods help agencies optimize material use. For example, use of MDSS in Indiana resulted in Statewide savings of $9,978,536 (188,274 tons) in salt usage and $979,136 (41,967 hours) in overtime compensation from the previous winter season.	***Measure captured to extent possible given available data*** • Reported results from literature search and RITA ITS Benefits Database. • While national numbers for salt use are available, normalizing salt use by State for evaluation purposes is a challenge. Variability in winter weather severity and in levels of service—from year to year and from place to place—makes performance measurement difficult.
Objective 7: Engage the climate change community in maintenance and operations	PM-22: Number of public agencies meeting "INVEST" and/or sustainability criteria related to road weather management	• There is a high number of States developing and implementing RWMP as well as fully or partially deployed an MDSS. • There is a mix in the level of goal setting and progress/performance measurement occurring across States. • Some best practices for snow and ice control exist but they are not uniform across the nation.	***Measure adequately captured*** • State DOTs, especially the northern-tier States meet many, if not all of the programmatic criteria identified in INVEST. • Major weaknesses pertain to performance measurement, use of standard operating practices and material management, which are more sporadic in its use across the nation.

Source: Battelle

Chapter 6 Summary and Recommendations

Summary

Periodic assessments of the performance of transportation program activities and accomplishments have been a priority of the USDOT as an essential tool for documenting goal attainment and providing guidance as programs evolve. The RWMP established a set of performance measures beginning in 2006 and began collecting data in order to assess progress toward meeting each of their major program goals under SAFETEA-LU. This report documents a careful review of the original measures and identifies new measures intended to fill gaps created by recent adjustments to the program in light of new legislation, emerging programs, and refinement of program goals and activities. The result of this, is an updated performance assessment document tracking continued progress in meeting each of the RWMP objectives.

Ideally, performance measurement will be carried out on a regular, periodic basis, perhaps bi-annually, focusing on improvements that can be assessed against a baseline of performance established in prior evaluations. By maintaining consistency in the measures of performance across the years, a more complete, long-term picture of RWMP performance can be obtained. However, with the sunset of SAFETEA-LU and implementation of MAP-21, the past two years have seen several major changes in RWMP direction and objectives. These changes, as well as evolving external conditions that also impact program performance, have resulted in modifications to the performance measures that were established for the initial assessment five years earlier. This report retained as many measures used previously as possible, consistent with recent programmatic changes, along with the addition of several new measures to allow assessment of progress toward the recently emerging RWMP objectives.

The measures used to assess the performance of the RWMP reflect both quantifiable outputs (e.g., number of agencies that have acquired an MDSS, or the number of training programs conducted) and qualitative outcomes (e.g., the extent to which agencies are using MDSS more effectively throughout their jurisdiction, or the proactive incorporation of road weather information by transportation operators in decision making and the benefits experienced from these activities). Some of the RWMP objectives can be assessed quite adequately with quantitative output measures. For example, assessing success at building partnerships can be measured by identifying the number of agencies that are working together on road weather projects, jointly developing new operational strategies, and participating in joint-agency meetings and workshops. Other objectives however, such as enhancing road weather knowledge and capabilities are more difficult to capture solely with quantitative output measures, such as attendance at training courses or RWMP website visits. It is assumed that actions taken by the RWMP to engage stakeholders and encourage their participation in various program activities will translate into the desired qualitative benefits, such as more effective use of tools or, ultimately, enhancements to traveler safety and mobility. A challenge for performance measurement is to gather the kinds of data that can support these more intangible qualitative outcomes; namely, measures that assess impacts and benefits.

The RWMP aims to accomplish its programmatic objectives that focus on widespread recognition among State DOTs and transportation agencies of the value of incorporating road weather data, tools, and research into their operations in support of traveler safety and mobility. While these objectives can be met by both RWMP direct activities as well as by agency actions and factors external to the RWMP, the RWMP needs to understand the independent effects of their program activities in achieving these objectives in order to implement continuous improvement in their programs and strategies. The initial performance assessment and this recent update assessment have sought to specify measures that can isolate the direct and indirect effects of the RWMP on goal attainment, though controlling for external effects remains challenging.

Various sources of data were used to quantify the measures, including sources used in the prior assessment along with new data sources. These included RWMP records of training, partnership and stakeholder engagement, the ITS Deployment Statistics and Benefit-Cost databases, literature reviews, and a focused RWMP sponsored survey of State DOTs. While not all data elements necessary for the full quantification of the measures were captured, these sources provided adequate primary sources to assess performance.

The RWMP desires to obtain performance measures that offer comparable indicators of progress across States. But there are many challenges to accomplishing this objective. For example, States use different indicators to measure how well they are managing and operating their transportation systems. Some States don't collect data to support performance measurement or use only a few indicators of performance. Assessing road weather management and operational performance directly is relatively new across State DOTs and many don't yet include road weather into their metrics. For those States that do focus on measuring performance in managing their transportation system under weather conditions, they lack effective tools to allow them to compare performance across weather events or over time. That is, they have difficulty being able to ascribe changes in performance to the independent effects of their operational actions when there is a lot of variability event-to-event and time-to-time in the nature and severity of the weather conditions. Only a few States responding to the survey conducted in this study reported that they have or use a winter weather severity index to normalize the variable effects of weather on their performance outcomes. The RWMP faces a similar challenge at the level of national performance assessment, comparing changes and benefits over time and variable weather conditions. The RWMP also desires to encourage consistency in performance metrics and methods across States and with their national approach to performance assessment.

This most recent assessment of progress across the country in meeting the RWMP objectives shows continuing adoption of advanced technologies, decision support tools, and more effective use of advanced road weather management strategies. However, there is ample room for improvement. Much of the attention in road weather management to date has been focused on dealing with winter weather challenges, and attention is only now beginning to include strategies for addressing non-winter weather problems, including rain, flooding, wind, fog, and weather effects on road maintenance and construction activities year round. Given the introduction and recent deployment of new tools and technologies for road weather (e.g., non-winter Maintenance and Operation Decision Support System – MODSS), those States willing to make early investments and take risks deploying these new approaches have done so through pilot projects and partial deployments in order to see whether they were cost effective and beneficial to their operations. Other States are taking a wait-and-see approach to these deployments, or are reluctant to make new investments in an environment of very constrained resources. Thus, there remains room for the RWMP to continue to encourage and support where possible moving partial deployments toward more complete Statewide deployments, and convincing other State DOTs to adopt proven strategies for effectively managing and operating their systems under a range of road weather conditions.

A little over half the State DOTs responded to the State survey used in this current study, and they were all concentrated in the northern half of the country. This presumably reflects the perceived primacy of winter weather among State DOT operational concerns as they relate to weather effects on their transportation systems, as well as the historical focus of the RWMP. In the future, the RWMP will need to explore more effective ways of drawing the southern tier State DOTs into their program by further expanding tools and resources toward supporting non-winter weather operations and emphasizing the importance of integrating weather into operations in these settings. From a performance assessment standpoint, it is important to broaden the measures to address outputs and outcomes of RWMP activities across the full national range of weather types and environments.

This report listed a number of challenges faced in the 2012 update of the measures, a number of which could not be overcome with the available data. These included:

- Assessing the impacts and benefits of partnerships, collaboration and training, such as increased awareness, knowledge, use and skills with regard to RWMP content (tools, research, etc.)
- The availability of mobile road weather data is increasing, but current availability and use are limited. As mobile data become more prominent, it will be important to employ measures of both the increased use of these data and assessment of their unique benefits over fixed data.
- New tools that can enhance the effectiveness of DOT operations, beyond the MDSS, include sophisticated modeling tools and dynamic mobility applications. This study showed very limited use of such tools at this time, but they are expected to become more widely available and used. Performance measures will need to address the uses and benefits of these new capabilities.
- New areas of national research focus, such as relate to the potential impacts of climate change on transportation, will be highly relevant for the RWMP. As RWMP activities are defined and implemented in this area, new performance measures will need to be developed and used to capture the effectiveness of RWMP activities in mitigating the adverse consequences of climate change.

Recommendations

Next steps in providing improved performance measurement should focus on qualitative outcome indicators of growth in capability, knowledge and skill that lead to increases in public safety and mobility. These recommended steps include the following:

- ***Introduce Performance Measurement as a Topic During Stakeholder Meetings***: Include this as a topic at stakeholder meetings at which the participants can share their perspectives on how to better assess these more elusive attributes of performance. The RWMP could then seek to encourage the adoption of a common, consistent set of qualitative output indicators across the States. In addition, the RWMP should offer guidance to the States regarding the kinds of data that need to be routinely collected and maintained in order to support long-term assessments.
- ***Work with Agencies to Agree on Best Practices***: Measuring safety benefits is particularly elusive and difficult due to the relative rarity of crashes and fatalities, the lack of data on the

role of weather in crashes, and the need to extend data collection and evaluation coverage over a sufficient period of time to be able to assemble sufficient data. The RWMP should work with the States and Federal traffic safety agencies to agree on a best practices approach to assessing the safety benefits of the RWMP.

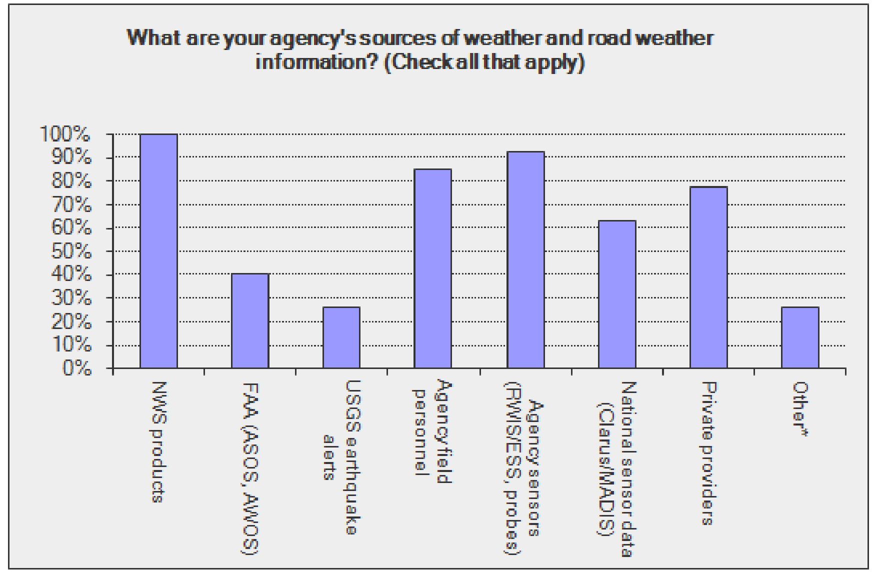
- ***Work with State DOTs to Develop Approach for Controlling for Weather Variability:*** The RWMP should work with the State DOTs to develop a common and consistent approach to controlling for variability in the type, occurrence and intensity of weather events over time in order to be able to more reliably assess the effects of operational actions on system performance.
- ***Work with Related Programs to Increase Awareness of RWMP Tools and Resources:*** Recent and emerging new legislation and research/action programs have direct relevance to the RWMP's efforts to assess their program performance. These new initiatives not only convey their own need for performance assessment, but also offer another mechanism to support innovation in measurement and encourage the incorporation of weather as a critical factor in affecting transportation program performance. Examples that have been mentioned in this report include the Section 1201 rule of SAFETY-LU that calls for real-time information programs at the State level on all interstates by November 2014, and MAP-21 that is providing funding to update transportation infrastructure and improved operations and performance. Another is the SHRP2 research program aimed at aging infrastructure, congestion and safety and offering solutions to improve transportation operations. The connected vehicle initiative offers clear opportunities to incorporate weather into an important operational program that will directly impact safety and mobility. The RWMP should work closely with these kinds of programs to leverage building greater awareness of the importance of road weather considerations and promotion of the more effective use of research, tools and other resources.
- ***Maintain Core Set of Measures for Evaluation:*** This report addressed the update to the RWMP performance assessment program in what is expected to be an on-going effort to document goal attainment. Going forward the RWMP should aim to establish a core set of measures that are applied consistently over time in order to support effective longitudinal analysis of program growth and performance. It is inevitable that program goals and objectives will be adjusted from time to time and that new external programs and activities will influence RWMP outcomes in unpredictable ways. Therefore, a subset of measures will need to be revised or new measures added to keep pace, but to the extent possible it will be advantageous to keep a core set of measures consistent for the duration of the program.

Finally, it is important to emphasize that, notwithstanding a variety of opportunities that can be identified where the RWMP can make further improvements, the results from this update study on program performance demonstrate substantial and continuing progress. Going forward, the RWMP, in collaboration with related programs, can use the results of these assessments to further encourage all State DOTs and transportation agencies to proactively bring weather information, tools and resources actively to bear in their operations, especially those States and agencies that have held back due to concerns with costs and risks. The evidence now overwhelmingly points to the advantages and potential cost savings associated with the adoption of road weather management strategies, both for DOT operations and for the traveling public.

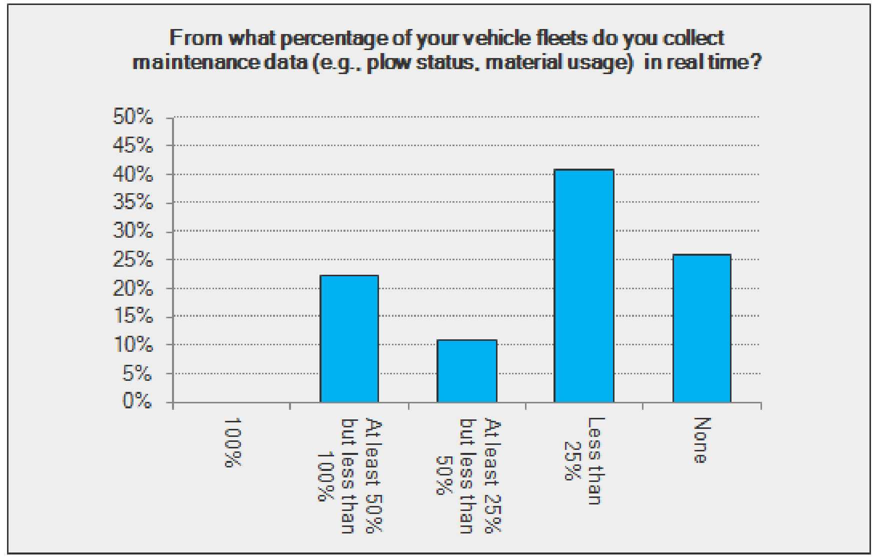
Appendix A. FHWA RWMP 2012 Performance Survey Results

Q2. What are your agency's sources of weather and road weather information? (Check all that apply)		
Answer Options	**Response Percent**	**Response Count**
NWS products	100.0%	27
FAA (ASOS, AWOS)	40.7%	11
USGS earthquake alerts	25.9%	7
Agency field personnel	85.2%	23
Agency sensors (RWIS/ESS, probes)	92.6%	25
National sensor data (*Clarus*/MADIS)	63.0%	17
Private providers	77.8%	21
Other*	25.9%	7
	Answered question	**27**
	Skipped question	**0**

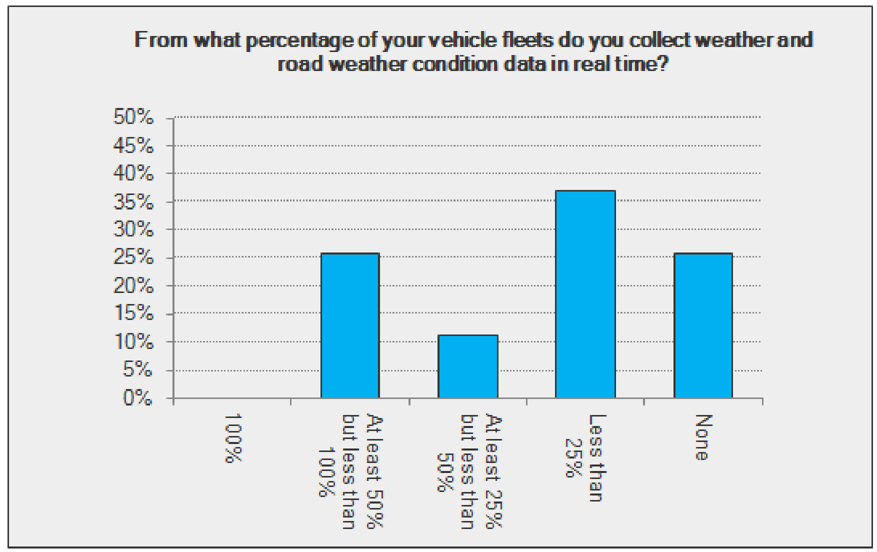
* -- Other internet based information used individually by maintenance personnel.
-- Private sector weather firms - Schneider Electric (Telvent DTN) & Murray & Trettel, Inc.
-- University consolidated data set from multiple souces.
-- MDSS Weather Service Provider.
-- Lyndon State College Meteorology Department.
-- Note that the agency field personnel reports are part of our 511 traveler information program which is closed tied to but branded differently than 511.
-- MDSS.



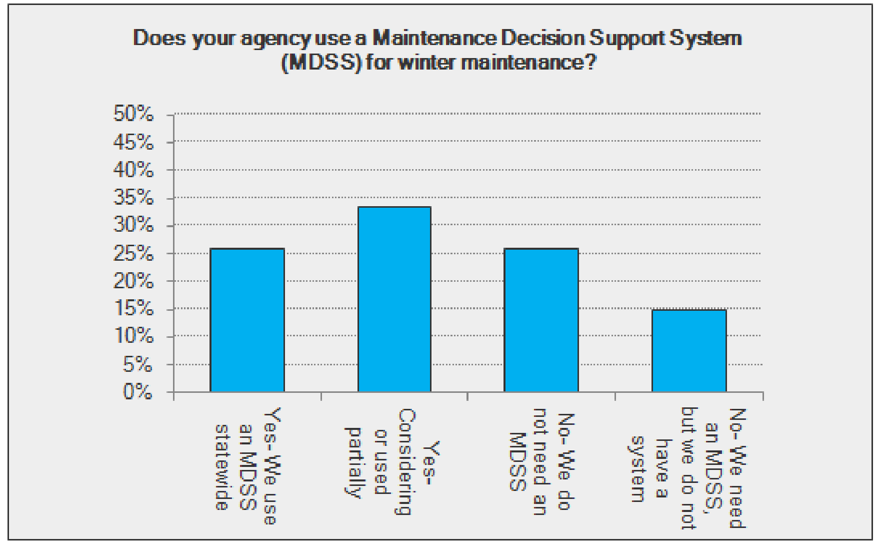
Q3. From what percentage of your vehicle fleets do you collect maintenance data (e.g., plow status, material usage) in real time?		
Answer Options	**Response Percent**	**Response Count**
100%	0.0%	0
At least 50% but less than 100%	22.2%	6
At least 25% but less than 50%	11.1%	3
Less than 25%	40.7%	11
None	25.9%	7
	Answered question	**27**
	Skipped question	**0**



Q4. From what percentage of your vehicle fleets do you collect weather and road weather condition data (air temperature, pavement temperature, barometric pressure, etc.) in real time?		
Answer Options	**Response Percent**	**Response Count**
100%	0.0%	0
At least 50% but less than 100%	25.9%	7
At least 25% but less than 50%	11.1%	3
Less than 25%	37.0%	10
None	25.9%	7
	Answered question	**27**
	Skipped question	**0**



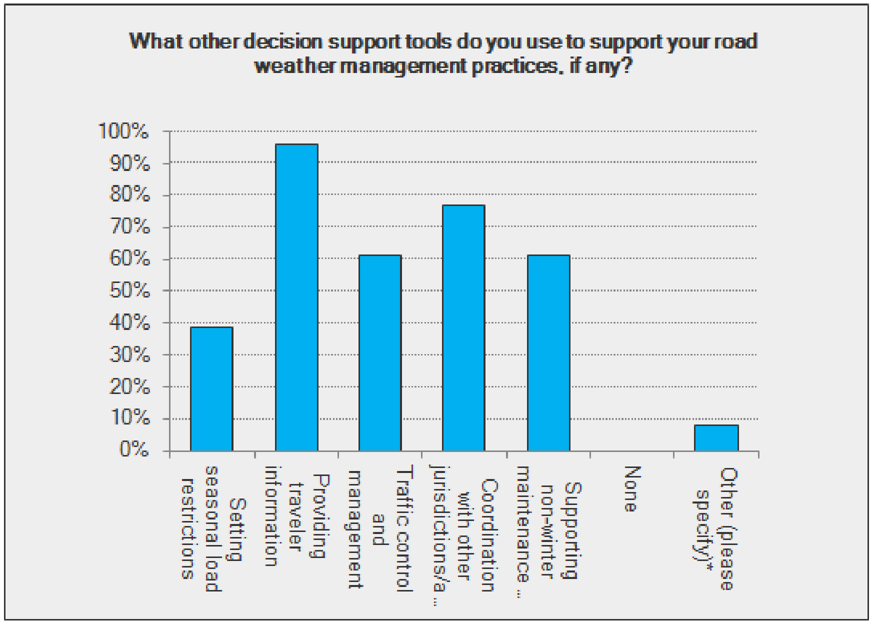
Q5. Does your agency use a Maintenance Decision Support System (MDSS) for winter maintenance? MDSS includes software that provides strategic and tactical weather forecasts, supports treatment decision making and provides summary reports of weather event performance. Please check one of the following options.		
Answer Options	**Response Percent**	**Response Count**
Yes- We use an MDSS statewide	25.9%	7
Yes- Considering or used partially	33.3%	9
No- We do not need an MDSS	25.9%	7
No- We need an MDSS, but we do not have a system	14.8%	4
	Answered question	**27**
	Skipped question	**0**



Q6. What other decision support tools do you use to support your road weather management practices, if any?		
Answer Options	**Response Percent**	**Response Count**
Setting seasonal load restrictions	38.5%	10
Providing traveler information	96.2%	25
Traffic control and management	61.5%	16
Coordination with other jurisdictions/agencies	76.9%	20
Supporting non-winter maintenance activities	61.5%	16
None	0.0%	0
Other (please specify)*	7.7%	2
Answered question		**26**
Skipped question		**1**

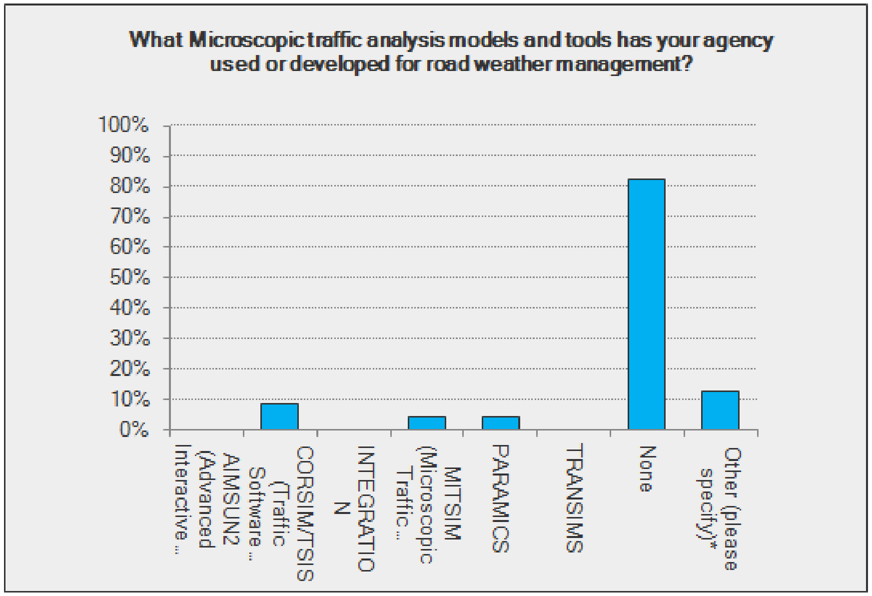
* -- Close monitoring of performance measurements derived from ATIS data during weather events

-- Alaska has an extensive network of temperature data probes and decision tools for seasonal weight restrictions



Q7. What Microscopic traffic analysis models and tools has your agency used or developed for road weather management?		
Answer Options	**Response Percent**	**Response Count**
AIMSUN2 (Advanced Interactive Microscopic	0.0%	0
CORSIM/TSIS (Traffic Software Integrated System)	8.7%	2
INTEGRATION	0.0%	0
MITSIM (Microscopic Traffic Simulator)	4.3%	1
PARAMICS	4.3%	1
TRANSIMS	0.0%	0
None	82.6%	19
Other (please specify)*	13.0%	3
	Answered question	23
	Skipped question	4

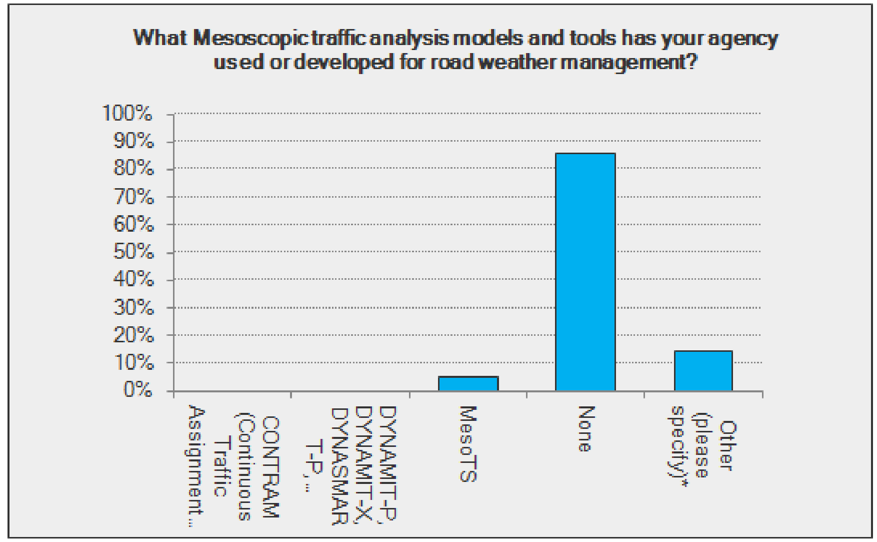
* -- SYNCHRO
-- Synchro, HCS2010, SIDRA, ITS Trip Generation Software, Quickzone, VISSIM, TRANSYT-7F
-- Don't know



Q8. What Mesoscopic traffic analysis models and tools has your agency used or developed for road weather management?

Answer Options	Response Percent	Response Count
CONTRAM (Continuous Traffic Assignment Model)	0.0%	0
DYNAMIT-P, DYNAMIT-X, DYNASMART-P,	0.0%	0
MesoTS	4.8%	1
None	85.7%	18
Other (please specify)*	14.3%	3
	Answered question	**21**
	Skipped question	**6**

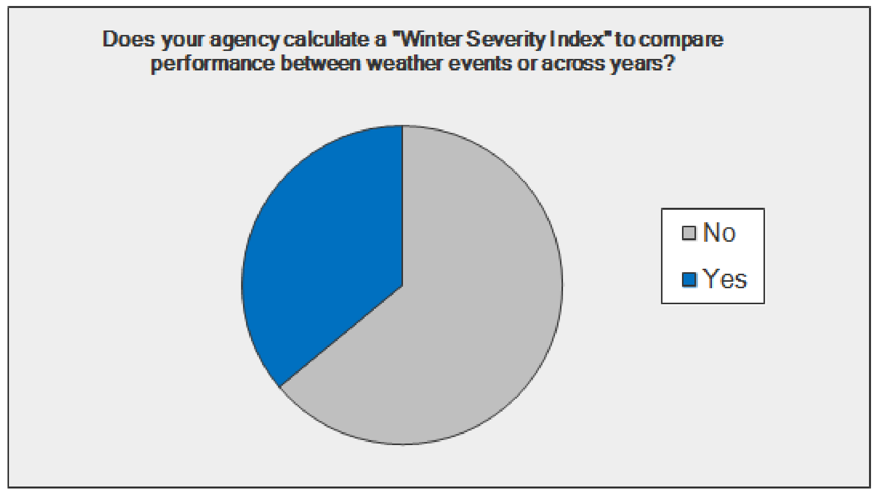
* -- Unknown
-- VISUM
-- Don't know



Q9. Does your agency calculate a "Winter Severity Index" to compare performance between weather events or across years?

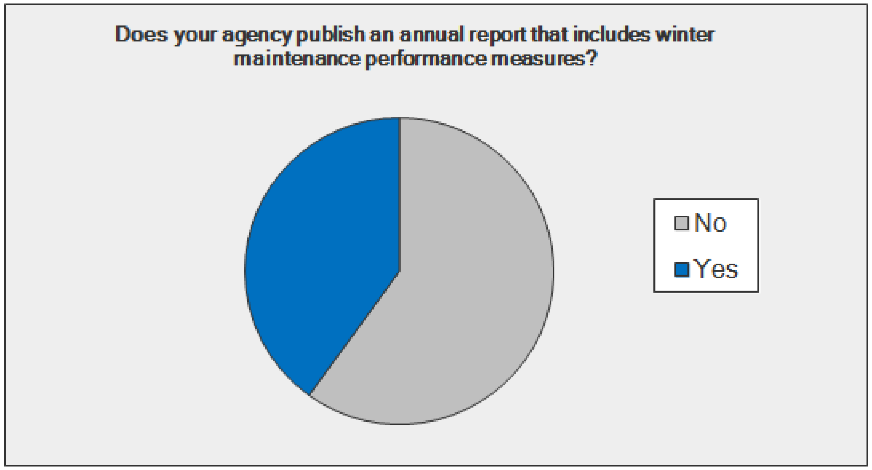
Answer Options	Response Percent	Response Count
No	64.0%	16
Yes	36.0%	9
Please provide a reference or link if available.*	28.0%	7
	answered question	**25**
	skipped question	**2**

* -- IL: We have an interest in developing one.
-- KS: Internally developed with State Climatologist
-- NY: For Municipal S&I Contracts we use NYSDOT plow/spread miles comparisons to rate severity.
-- ME: We use storm count and we're moving to storm hours.
-- WY: We are working on this but it is not complete
-- SD: Just experimentally at present
-- RI: WSI developed by Clear Roads



Q10. Does your agency publish an annual report that includes winter maintenance performance measures?		
Answer Options	**Response Percent**	**Response Count**
No	57.7%	15
Yes	38.5%	10
Please provide a reference or link if available.*	15.4%	4
Answered question		**26**
Skipped question		**1**

* -- KS: http://kdotapp.ksdot.org/perfmeasures/ Go to Operations, Snow and Ice, click on bottom of graph
-- ME: High level performance measures.
-- OR: We do have some performance data published in our quarterly business report
-- VT: http://www.aot.state.vt.us/

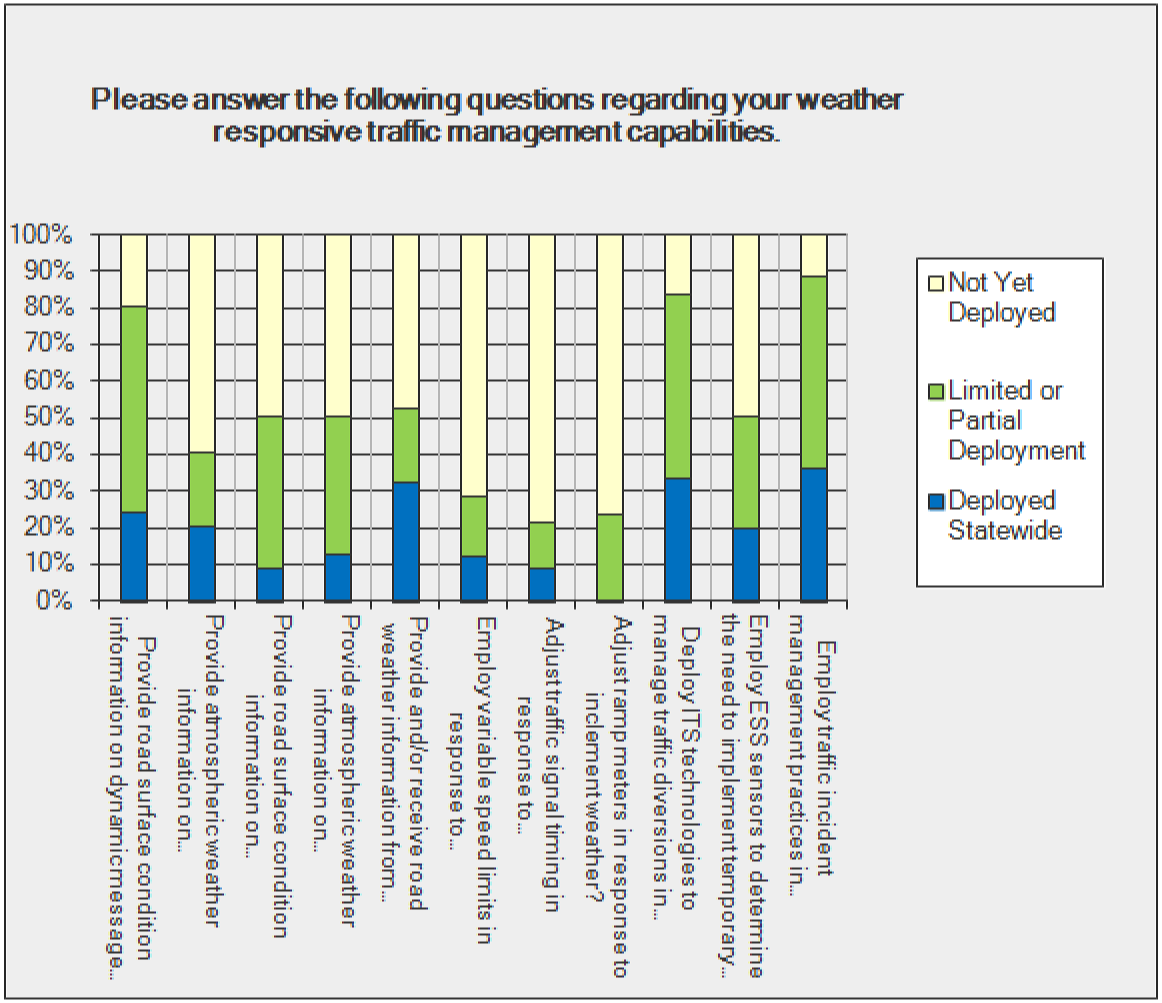


Additional references to notes above:

KS: http://kdotapp.ksdot.org/perfmeasures/documents/2011_snow_and_ice_fact_sheet.pdf

VT: http://vtransoperations.vermont.gov/sites/aot_operations/files/documents/AOT-OPS_WINTER_SERVICES_GUIDE.pdf

Q11. Please answer the following questions regarding your weather responsive traffic management capabilities.					
Answer Options **Does your state:**	**Deployed Statewide**	**Limited or Partial Deployment**	**Not Yet Deployed**	**Response Count**	**Skipped Question**
Provide road surface condition information on dynamic message signs?	6	14	5	25	2
Provide atmospheric weather information on dynamic message signs?	5	5	15	25	2
Provide road surface condition information on highway advisory radio?	2	10	12	24	3
Provide atmospheric weather information on highway advisory radio?	3	9	12	24	3
Provide and/or receive road weather information from agency-hosted Twitter accounts?	8	5	12	25	2
Employ variable speed limits in response to inclement weather?	3	4	18	25	2
Adjust traffic signal timing in response to inclement weather?	2	3	19	24	3
Adjust ramp meters in response to inclement weather?	0	6	20	26	1
Deploy ITS technologies to manage traffic diversions in response to road closures for inclement weather?	8	12	4	24	3
Employ ESS sensors to determine the need to implement temporary restrictions on vehicles during inclement weather (e.g., road closures to high-profile vehicles during periods of high winds, snow tire/chain requirements during winter weather)?	5	8	13	26	1
Employ traffic incident management practices in response to inclement weather (e.g., prepositioning assets, quick clearance during weather, etc.)?	9	13	3	25	2
				Answered one or more questions	**26**
				Skipped all questions	**1**


Please answer the following questions regarding your weather responsive traffic management capabilities.
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Provide road surface condition information on dynamic message...
Provide atmospheric weather information on...
Provide road surface condition information on...
Provide atmospheric weather information on...
Provide and/or receive road weather information from...
Employ variable speed limits in response to...
Adjust traffic signal timing in response to...
Adjust ramp meters in response to inclement weather?
Deploy ITS technologies to manage traffic diversions in...
Employ ESS sensors to determine the need to implement temporary...
Employ traffic incident management practices in...
Not Yet Deployed
Limited or Partial Deployment
Deployed Statewide

This page intentionally left blank.

Appendix B. List of Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ADVISE	Adverse Visibility Information System Evaluation
AMS	American Meteorological Society
ASOS	Automated Surface Observing Systems
ATM	Active Traffic Management
AVL	Automatic Vehicle Location
AWOS	Automated Weather Observing System
BAA	Broad Agency Announcement
BMPs	Best Management Practices
CITE	Consortium for ITS Training and Education
CVO	Commercial Vehicle Operations
DMS	Dynamic M. age Signs
DOT	Department of Transportation
ESS	Environmental Sensor Station
FAA	Federal Aviation Administration
FARS	Fatality Analysis Report System
FHWA	Federal Highway Administration
FI	Frost index
GES	General Estimates System
HAR	Highway Advisory Radio
IMO	Integrated Mobile Observations
INDOT	Indiana Department of Transportation
ITE	Institute for Transportation Engineers
ITS	Intelligent Transportation Systems
ITS-JPO	Intelligent Transportation Systems Joint Program Office
LOS	Level of Service
MADIS	Meteorological Assimilation Data Ingest System
MAP-21	Moving Ahead for Progress in the 21st Century Act
MDSS	Maintenance Decision Support System
MHA	Massachusetts Highway Administration
MPOs	Metropolitan Planning Organizations
NASBO	National Association of State Budget Officers
NASS	National Automotive Sampling System

NCAR	National Center for Atmospheric Research
NHTSA	National Highway Traffic Safety Administration
NMVCCS	National Motor Vehicle Crash Causation Survey
NOAA	National Oceanic and Atmospheric Administration
NTOC	National Transportation Operations Coalition
NWS	National Weather Service
OEI	Operations Efficiency Index
OFCM	Office of the Federal Coordinator for Meteorology
OHPI	Office of Highway Policy Information
PFS	Pooled Fund Study
PIARC	National Committee of the USA World Road Association
R&D	Research and Development
RFIs	Requests for Information
RITA	Research Innovative and Technology Administration
RITIS	Regional Integrated Transportation Information System
RWIDS	Road-Weather Integrated Data System
RWIS	Road Weather Information System
RWMP	Road Weather Management Program
RWRI	Road Weather Resource Identification
SAFETEA-LU	Safe, Accountable, Flexible, Efficient, Transportation Equity Act – A Legacy for Users
SCOM	Subcommittee on Maintenance
SHRP2	Strategic Highway Research Program 2
SICOP	Snow and Ice Pooled Fund Cooperative Program
SOP	Standard Operating Procedure
TMC	Traffic Management Center
TRB	Transportation Research Board
TrEPS	Traffic Estimation and Prediction Systems
USDOT	United States Department of Transportation
USGS	United States Geological Survey
VDT	Vehicle Data Translator
VSL	Variable Speed Limit
WDE	Weather Data Environment
WRTM	Weather Responsive Traffic Management
WSI	Weather Severity Index

U.S. Department of Transportation
ITS Joint Program Office-HOIT
1200 New Jersey Avenue, SE
Washington, DC 20590

Toll-Free "Help Line" 866-367-7487
www.its.dot.gov

FHWA-JPO-13-87

U.S. Department of Transportation