2015 Road Weather Management Performance Measures Survey, Analysis, and Report

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The Federal Highway Administration’s Road Weather Management Program (RWMP) established a set of performance measures and began collecting data in order to assess progress toward its stated objectives. Assessments of the program’s performance were completed in 2009 and 2012, and the program has continued to evolve over time, informed by past performance and influenced by emerging trends and technology. The RWMP continues to conduct a periodic review of its performance indicators to ensure that the performance measures reflect the changes in program objectives as well as the broader policy context. The 2015 Road Weather Management Performance Measures Report is the next iteration of this periodic review of the RWMP’s performance and an update to the 2012 report. Twenty-seven performance measures are quantified as part of this update to assess performance across the program’s eight objectives.</td></tr>
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EXECUTIVE SUMMARY

Nearly a decade ago, the Federal Highway Administration's Road Weather Management Program (RWMP) established a set of performance measures 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). Over the years, the Federal Highway Administration (FHWA) RWMP has been actively involved in various programs, projects, and activities to help state and local agencies improve the performance of the transportation system during adverse weather conditions. Assessments of the program's performance were completed in 2009 and 2012, and the program has continued to evolve over time, informed by past performance and influenced by emerging trends and technology. The RWMP continues to conduct a periodic review of its performance indicators to ensure that the performance measures reflect the changes in program objectives as well as the broader policy context. The *2015 Road Weather Management Performance Measures Report* is the next iteration of this periodic review of the RWMP's performance and an update to the 2012 report.

ES 1. Updated Performance Measures

Ideally, maintaining consistency in the types of performance measures allows for more complete, long-term assessments of a program. This 2015 update identified necessary changes to address gaps in performance measurement due to current program objectives and activities and recent advances in capability and technology for road weather management. The gaps that were identified in the previous performance measurement framework include:

- Extent of use and adoption of mobile data-based applications.
- Climate change/extreme weather/resilience.
- Section 1201 rule compliance.
- Meteorological Assimilation Data Ingest System (MADIS) transition.
- Expanding partnerships.
- Mainstreaming of road weather management programs.
- Performance measurement/continuous improvement of road weather management programs.

As a result, seven new performance measures were added in the 2015 performance measure update. The final list of performance measures are shown in Table ES- 1 below and are organized by Objective. New measures are highlighted in **bold** within the table.

Table ES-1. Road Weather Management Program Performance Measures for 2015.

Objective 1: Build and sustain relationships with multi-disciplinary partners to expand road weather management deployments
PM #1: Number of agencies participating in road weather R&D projects
PM #2: Number of agencies participating in, and benefiting from, road weather management stakeholder meetings/workshops
Objective 2: Ensure road weather management investments improve highway performance
PM #3: Number of agencies that collect and report road weather-related performance measures to the public (i.e. winter severity index, mobility index, etc.)
PM #4: Number of agencies that have a process for evaluating the return on investment or net benefit of their road weather management investments
PM #5: Reductions in agency costs of weather-related maintenance and operations activities
PM #6: Reduction in number and types of fatalities and crashes attributed to adverse weather nationally
PM #7: Reduction in the extent of capacity losses and delays due to fog, snow, and ice events including freight
PM #8: Increase in travel time reliability or decrease in variability due to road weather management strategies during adverse weather scenarios
PM #9: Reduction in the number of tons of salt or chemical usage in the U.S. normalized by Winter Severity Index
Objective 3: (Advance) Transportation, weather, and research communities' use of and reliance on fixed and mobile road weather observations
PM #10: Number of State departments of transportation (DOTs) that are participants in the MADIS program
PM #11: Number of State DOTs that subscribe to road weather products and services
PM #12: Number of State DOTs collecting mobile observations of road weather data from appropriate vehicle fleets
PM #13: Number of State DOTs reporting the use of ESS in operations and maintenance activities
Objective 4: Advance the state-of-the-art for mobile sensing and integrating vehicle data into road weather applications
PM #14: Number of/percentage of responding agencies using mobile data-based applications in road weather management
Objective 5: Advance the state-of-the-practice by promoting tailored management strategies for different regions
PM #15: Number of States disseminating weather advisory and other road weather information to travelers
PM #16: Number of agencies using control and treatment strategies during weather events
PM #17: Number of agencies that have participated in or conducted RWM capability maturity assessment exercises
PM #18: Number of agencies that coordinate with their local forecast offices for road weather management and operations

Table ES-1. Road Weather Management Program Performance Measures for 2015. (Continuation)

Objective 6: Weather-related decision support technologies are integrated into traffic operations and maintenance procedures
PM #19: Number of agencies adopting MDSS technologies and methods
PM #20: Number of agencies using other weather-related decision-support tools
PM #21: Number of agencies reporting use of appropriate analysis tools to factor weather impacts and strategies
Objective 7: Advance the state-of-the-practice by raising road weather capabilities and awareness across the transportation and weather communities
PM #22: Number of agencies and attendees who have taken any of the training courses and workshops sponsored by the RWMP
PM #23: Number of agencies and participants in road weather management webinars led by the RWMP
PM #24: Number of meetings, site visits or venues where road weather management presentations/briefings were made
PM #25: Number of hits/visits to RWMP websites
Objective 8: Operations community is engaged with climate change & sustainability communities
PM #26: Number of public agencies meeting sustainability criteria related to road weather management
PM #27: Number of agencies conducting vulnerability/risk assessments, developing/implementing resiliency plans or adaptation plans, for their road weather management infrastructure and processes to respond to climate change and extreme weather

DOT – department of transportation ▪ ESS – environmental sensor station ▪ MADIS – Meteorological Assimilation Data Ingest System ▪ MDSS – maintenance decision support systems ▪ PM – performance measure ▪ R&D – research and development ▪ ROI – return on investment ▪ RWM – road weather management ▪ RWMP – road weather management program

ES.2 Road Weather Management Program Performance and Results

Objective 1: Build and sustain relationships with multi-disciplinary partners to expand Road Weather Management deployments. Partnerships with State departments of transportation (DOTs) and local agencies are critical to implementing the RWMP's research agenda for road weather management. The RWMP encourages transportation agencies to participate in demonstrations and pilot projects for a number of innovative road weather research areas, including fostering cross-entity collaboration to coordinate road weather messaging for travelers; developing a nationwide network of environmental sensor stations (ESS) to provide web-based accessibility to real-time data for atmospheric and pavement observations; and advancing the use of vehicle sensor technology to collect data about atmospheric and pavement conditions. This objective includes two performance measures that assess the breadth and depth of RWMP's stakeholder engagement, shown in Table ES- 2.

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

PM #1: Number of agencies participating in road weather Research and Development R&D projects
• Four (4) State DOTs are currently participating in the Pathfinder Project. • Seven (7) public agencies have participated in the development and use of the RWMP Capability Maturity Framework. • Three (3) State DOTs have participated in the IMO program. • Seven (7) State DOTs have been involved in V2I implementation activities. • Twenty-four (24) State DOTs have participated in weather data environment research activities. including transitioning to MADIS from *Clarus*. • Five (5) State DOTs have been involved in WRTM implementation support activities.
PM #2: Number of agencies participating in, and benefiting from, road weather management stakeholder meetings/workshops
• The number of State DOTs attending the annual RWMP meetings has decreased with more than a 50 percent reduction over two years (2012 to 2014). However, the overall attendance in Stakeholder workshops is increasing with a greater proportion of private sector attendees. • Majority of participants expressed that the meetings and workshops met or exceeded their expectations and provided information that is useful and relevant to their duties.
DOT – department of transportation ▪ IMO – integrated mobile observations ▪ PM – performance measure ▪ R&D – research and development ▪ RWMP – road weather management program ▪ V2I – vehicle to infrastructure ▪ WRTM – weather responsive traffic management

Objective 2: Ensure road weather management investments improve highway performance. Through implementation of various activities, products, and services supported by the RWMP and growing capabilities at State and local agencies, meaningful improvements in highway performance are expected nationally during adverse weather conditions. The six measures shown in Table ES- 3 are used to monitor progress and performance to identify how program activities are contributing to overall performance of the highway system.

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

PM #3: Number of agencies that collect and report road weather-related performance measures to the public
• Among the State DOTs surveyed, 23 DOTs reported regularly collecting and reporting some form of road weather performance measures. Eight States reported they did not collect and report road weather performance measures, and eight respondents were uncertain.
PM #4: Number of agencies that have a process for evaluating the return on investment or net benefit of their road weather management investments
• The majority of States reported that they did not have a process or were not sure regarding evaluating ROI or the net benefits of road weather management investments. • Out of the respondents, five agencies do have a process in place.
PM #5: Reductions in agency costs of winter weather-related maintenance and operations activities
• Since the publication of the 2012 report, limited evaluation reports have been published documenting savings, but published case studies continued to show that winter maintenance costs decreased as the use of weather information increased or its accuracy improved. • Michigan DOT's benefit-cost calculations for deployment of RWIS and Maintenance Tracking using GPS were positive. • Idaho DOT's use of RWIS to monitor winter maintenance response has demonstrated significant reductions in winter maintenance costs.
PM #6: Reduction in number and types of fatalities and crashes attributed to adverse weather nationally
• Although the national level data had been showing a decreasing trend of the number of fatal crashes occurring during inclement weather, 2013 shows a slight increase. • Practices such as variable speed management systems, ice warning systems, and automated anti-icing spray systems have demonstrated significant benefits. For example, in Colorado, implementation of a variable speed management system consisting of a complete RWIS, resulted in zero winter related crashes in one section of highway in Snowmass Canyon.
PM #7: Reduction in the extent of capacity losses and delays due to fog, snow, and ice events including freight
• Although limited evaluations have been found beyond those reported in 2012, systems have been implemented which demonstrated benefits on traffic flow. • One example came from Utah, which implemented a weather responsive signal control system. During severe winter weather events, travel times were improved by 3 percent and reduced overall stopped times by 14.5 percent.
PM #8: Increase in travel time reliability or decrease in variability due to road weather management strategies during adverse weather scenarios
• No new reliability-related studies for weather were found since 2012. • Very few agencies track reliability measures, and even the ones that do, do not distinguish between the various causes of reliability.

Table ES-3. Summary of Objective #2 Performance Measures. (Continuation)

PM #9: Reduction in the number of tons of salt or chemical usage in the U.S. normalized by Winter Severity Index
• The use of a WSI has continued to gain recognition as a way to gauge the relative severity of winter weather across various time frames or geographic regions. • Idaho DOT has reported a significant reduction in winter maintenance costs due to the use of a winter mobility index.

DOT – department of transportation ▪ GPS – global position system ▪ PM – performance measure ▪ R&D – research and development ▪ ROI – return on investment ▪ RWIS – road weather information systems ▪ WSI – winter severity index

Objective 3: Transportation, weather, and research communities use and rely upon fixed and mobile road weather observations. The transition from *Clarus* to MADIS signals momentum towards the creation of a national operational system of real-time (or near real-time) and archived observational road weather data. Ultimately, MADIS will offer a robust set of quality data that will be available to support traffic management, inform maintenance decision-making and performance measurement, and provide information on current conditions to the traveling public. The performance measures under Objective 3 capture progress towards continued growth in the use of fixed and mobile road weather observations by State DOTs, as shown in Table ES- 4. Additionally, this objective not only examines the availability of data, but also the subscription rates and use of observational data at State DOTs – which gauge the impact of the availability of data on strategic and tactical decision-making for weather-related maintenance and traffic operations.

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

PM #10: Number of State departments of transportation that are participants in the Meteorological Assimilation Data Ingest System program
• Twelve (12) States have participated in the MADIS program as of April 2015.
PM #11: Number of State departments of transportation that subscribe to road weather products and services
• Results show that subscription to National Weather Service Products held steady since 2013. • There has been a slight increase in the use of agency sensors (automated surface observing system [RWIS] probes), and a slight decrease in use of Private Weather Service Providers, agency field personnel, and Federal Aviation Administration (automated surface observing system [ASOS], automated weather observing system [AWOS]) products. • There was decline in the use of National Sensor Data sources (i.e., MADIS or previously *Clarus*), likely attributed to the recent transition from *Clarus* to MADIS and probably a temporary decline as full transition between MADIS and *Clarus* occurs.

Table ES-5. Summary of Objective #3 Performance Measures. (Continuation)

PM #12: Number of State departments of transportation collecting mobile observations of road weather data from appropriate vehicle fleets
• Overall, 50 percent of States surveyed collect real-time field data from maintenance vehicles. • Results of the survey show that collecting data fleet-wide is starting to become a practice; as many as three DOTs reported using 100 percent of the fleet to collect data, compared to zero in 2013.
PM #13: Number of State departments of transportation reporting the use of environmental sensor station in operations and maintenance activities
• In the State DOT survey, the respondents reported a total of 2,473 ESS, which is a slight decrease from the previous update. • Ninety-five percent of State DOTs reported using ESS data for decision-making. Majority of agencies also use ESS data to provide current conditions to traveler information systems (61 percent) and input for segment-level forecasts (58 percent).
ASOS – automated surface observing system ▪ AWOS – automated weather observing system ▪ DOT – department of transportation ▪ ESS – environmental sensor station ▪ MADIS – Meteorological Assimilation Data Ingest System ▪ PM – performance measure ▪ RWIS – road weather information systems

Objective 4: Advance the state of the art for mobile sensing and integrating vehicle data into road weather applications. Translating mobile and fixed observations to meaningful applications to solve problems for road weather management is the goal for this objective. Building from the growing number of States collecting mobile data, activities under this objective are geared towards showcasing applications that demonstrate the added value of mobile sensing in road weather management. However, very few States reported having applications that leverage mobile data to date but this is an area of growing interest and capability. The performance measure shown in Table ES- 5 tracks progress for this objective.

Table ES-6. Summary of Objective #4 Performance Measure.

PM #14: Number of/percentage of responding agencies using mobile data-based applications in road weather management
• Fifty-eight (58) percent of States are considering developing applications to take advantage of data collected from mobile platforms like equipped vehicles.
PM – performance measure

Objective 5: Advance the state of the practice by promoting tailored management strategies for different regions. There is not a universal approach to developing and implementing strategies to address winter weather. On the contrary, there are a wide range of potential methods and strategies that can be tailored to address the unique local conditions (pavement conditions, etc.). The RWMP encourages State DOTs to create a customized approach to road weather management that accounts for the local context (e.g., road conditions, forecasts, etc.). The activities under Objective 5 assess the variability of management strategies and methods used by State DOTs in order to consider local conditions. Four performance measures are used to document progress for this objective, as shown in Table ES- 6.

Table ES-7. Summary of Objective #5 Performance Measures.

PM #15: Number of States disseminating weather advisory and other road weather information to travelers
• After significant increases between 2004 and 2007, the use of websites/social media and dynamic message sign (DMS) steadied around the same level in 2015. • There was a significant increase in the use of 511 to disseminate information to travelers, while the use of Highway Advisory Radio (HAR) decreased. • Overall, providing road condition information on DMS is more prevalent, followed by agency hosted social media and other mobile applications. Road condition information on DMS and HAR are the most widely deployed.
PM #16: Number of agencies using control and treatment strategies during weather events
• The most widely deployed strategy, either partially or statewide, is employing traffic incident management practices (83 percent). • The least commonly used strategy is ramp meter adjustment (20 percent).
PM #17: Number of agencies that have participated in or conducted road weather management capability maturity assessment exercises
• The framework was recently developed in 2014. While participation in these exercises is currently low, the RWMP anticipates that capability maturity exercises will increase and intends to track the participation levels in the coming years.
PM #18: Number of agencies that coordinate with their local forecast offices for road weather management and operations
• Seventy-five (75) percent of respondents reported at least some coordination with the National Weather Service (NWS) local forecast office. • Nearly 8 percent of DOTs reported using publicly available information provided by the media and NWS, despite not having direct coordination.
DMS – dynamic message sign ▪ DOT – department of transportation ▪ HAR – Highway Advisory Radio ▪ NWS – National Weather Service ▪ PM – performance measure ▪ RWM – road weather management ▪ RWMP – road weather management program

Objective 6: Weather-related decision support technologies are integrated into traffic operations and maintenance procedures. The implementation of weather-related decision support technologies help State DOTs deploy a more sophisticated approach to traffic operations and maintenance by factoring in the impact of adverse weather conditions. The activities under Objective 6, shown in Table ES- 7, examine the various ways in which weather-related decision support technologies can be integrated into agency decision-making.

Table ES- 8. Summary of Objective # 6 Performance Measures.

PM #19: Number of agencies adopting maintenance decision support systems technologies and methods
• The percentage of State DOTs with statewide MDSS deployment has remained constant, and partial MDSS use has decreased. • Perhaps more significant is that the number of State DOTs expressing a need for MDSS increased, with a corresponding decrease in those agencies reporting no need for a system.

Table ES-7. Summary of Objective # 6 Performance Measures. (Continuation)

PM #20: Number of agencies using other weather-related decision-support tools
• Respondents indicate an overall decrease in the use of weather-related decision support tools for road weather management, and a few states (12.5 percent) reported not using any tools. • Providing traveler information remains the most used tool, followed by coordination with other agencies, support of non-winter maintenance, traffic control and management, and seasonal load restrictions.
PM #21: Number of agencies reporting use of appropriate analysis tools to factor weather impacts and strategies
• Fifty (50) percent of the respondents either did not use or were not aware of whether their agency used weather-responsive analysis tools and models, while still low is less than the previous update**.**
DOT – department of transportation ▪ MDSS – maintenance decision support systems ▪ PM – performance measure

Objective 7: Advance the state of the practice by raising road weather capabilities and awareness across the transportation and weather communities. Professional development is critical to advancing the RWM state of the practice. To this end, the RWMP provides resources to enhance the capabilities of both new and seasoned RWM practitioners. These activities include training courses and workshops, webinars to raise awareness of new research and resources, and the information and resources available on the RWMP website. Objective 7 assesses the effectiveness of RWMP's continuing efforts to support professional development of RWM practitioners, as shown in Table ES- 8.

Table ES-9. Summary of Objective #7 Performance Measures.

PM #22: Number of agencies and attendees who have taken any of the training courses and workshops sponsored by the Road Weather Management Program
• Thirteen training courses and workshops were held for transportation practitioners – eight were offered by RWMP, and five by Consortium for ITS Training and Education (CITE). • A total of 267 attendees participated in these training courses. Participants included staff from State DOTs, local agencies, private consultants, and federal agencies.
PM #23: Number of agencies and participants in road weather management webinars led by the Road Weather Management Program
• Three RWMP webinars have been held in 2014-2015. • Three hundred eighty-two (382) people have participated in the RWMP webinars.
PM #24: Number of meetings, site visits, or venues where road weather management presentations/briefings were made
• In the 2013-2014 timeframe, RWMP was represented by program staff or support contractors in nearly 60 meetings. • The breadth of meetings that feature RWMP presentations, as well as consistent participation (i.e., multiple-year attendance) continues.

Table ES-8. Summary of Objective #7 Performance Measures. (Continuation)

PM #25: Number of hits/visits to RWMP website
• Limited website statistics indicate increases in RWMP website use from previous update.

CITE – Consortium for ITS Training and Education ▪ DOT – department of transportation ▪ PM – performance measure ▪ RWMP – road weather management program

Objective 8: Operations community is engaged with climate change & sustainability communities. As climate changes, extreme weather and sustainability become more of a concern to State DOTs. The RWMP continues to highlight the important role that transportation systems management and operations have in ensuring that current and future program effectiveness is maintained. In many ways, activities in this objective are geared towards mitigating the economic, environmental, and social risks of changes occurring to the transportation system. The two measures in Table ES- 9 provide an assessment of how State DOTs are viewing sustainability, climate change, and extreme weather.

Table ES- 10. Summary of Objective #8 Performance Measures.

PM #26: Number of public agencies meeting sustainability criteria related to road weather management
• DOTs reported progress towards developing and implementing sustainability criteria related to road weather management as identified by Infrastructure Voluntary Evaluation Sustainability Tool (INVEST). • An overwhelming majority (95 percent) of State DOTs are pursuing some sort of sustainability effort related to road weather management. • The most common sustainability activity among State DOTs is having a documented standard of practice (SOP) for snow and ice control. The least common is having a dedicated road weather management program.
PM #27: Number of agencies conducting vulnerability/risk assessments, developing/implementing resiliency plans or adaptation plans, for their road weather management infrastructure and processes to respond to climate change and extreme weather
• The results support this is an emerging area of practice. • Thirty-six (36) percent expressed being uncertain about their State's activities related to climate change and extreme weather. • Thirty-one (31) percent reported having developed/implemented process for responding to extreme weather.

DOT – department of transportation ▪ INVEST – Infrastructure Voluntary Evaluation Sustainability Tool ▪ PM – performance measure ▪ SOP – standard of practice

Conclusions

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. Performance measures have been quantified in 2010 and 2012. This report documents a comprehensive review of the existing measures and identifies new measures intended to fill gaps created by recent adjustments to the program in light of new legislation, emerging initiatives, and refinement of program goals and activities. The result is an updated

performance assessment document tracking continued progress in meeting each of the RWMP objectives focused on activities occurring in the 2012-2015 timeframe.

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. The update received responses from 40 State DOTs which is a significant increase from the previous update of 28 State responses highlighting the primacy of road weather among State DOT operational concerns. The update includes a number of challenges also encountered in the previous 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 becomes 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.

Recommendations

Based on the results of the performance measurements, the following recommendations are offered to the RWM Program:

- Catalog best practices in State DOT performance measurement and disseminate performance reports reported by State DOTs.
- Continue developing methodologies and case studies related to benefit-cost analysis for road weather management.
- Improve tracking of participation and long-term outcomes of training, meetings, and workshops.
- Cultivate a knowledge and technology transfer effort to increase awareness of RWMP tools and resources.
- Develop program area focus around resilience and risk.
- Maintain State DOTs engagement around analysis, modeling, and simulation tools.
- Support stakeholder interest in mobile data and connected vehicle applications.

Going forward, the RWMP, in collaboration with related FHWA, State, Pooled Fund 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 into their operations, especially those States and agencies that have held back due to concerns with costs and risks.

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AASHTO – American Association of State Highway and Transportation Officials
AERIS – Applications for the Environment: Real-Time Information Synthesis
AMS – American Meteorological Society
APWA – American Public Works Association
ASOS – automated surface observing system
ATDM – active transportation and demand management
ATM – active traffic management
AWOS – automated weather observing system
AVL – automatic vehicle location
BASC – Board on Atmospheric Sciences and Climate
BCA – benefit/cost analysis
CAMP – Crash Avoidance Metrics Partnership
CATT – Center for Advanced Transportation Technology
CITE – Consortium for ITS Training and Education
CMF – compatibility maturity framework
CMM – Capability Maturity Model
CV – connected vehicle
CVRIA – connected vehicle reference implementation architecture
DCM – Data Capture and Management program
DMA – dynamic mobility application
DMS – dynamic message sign
DOT – department of transportation
EMDSS – enhanced maintenance decision support system
ESS – environmental sensor station
FAA – Federal Aviation Administration
FAST – fixed automated spray technologies
FHWA – Federal Highway Administration
FARS – Fatality Analysis Reporting System
FI – frost index
GES – General Estimates System
GPS – global position system
HAR – Highway Advisory Radio
HCM – Highway Capacity Manual
ICWS – ice curve warning system
IMO – integrated mobile observations
INVEST – Infrastructure Voluntary Evaluation Sustainability Tool
ITD – Idaho Transportation Department
ITE – Institute of Transportation Engineers
ITS – intelligent transportation systems
ITS-JPO – Intelligent Transportation Systems – Joint Program Office
ITSA – Intelligent Transportation Systems of America
ITS America – Intelligent Transportation Society of America
KTT – knowledge and technology transfer
MADIS – Meteorological Assimilation Data Ingest System

LIST OF ABBREVIATIONS AND SYMBOLS (CONTINUED)

MAP-21 – Moving Ahead for Progress in the 21st Century Act
MAW – motorists' advisories and warnings
MDSS – maintenance decision support systems
MVMT – million vehicle miles traveled
NASS – National Automotive Sampling System
NCAR – National Center for Atmospheric Research
NCHRP – National Cooperative Highway Research Program
NHTSA – National Highway Traffic Safety Administration
NMVCCS – National Motor Vehicle Crash Causation Survey
NOAA – National Oceanic and Atmospheric Administration
NOCoE – National Operations Center of Excellence
NTCIP – National Transportation Communications for ITS Protocol
NWS – National Weather Service
O&M – operations and maintenance
OAR – Office of Oceanic & Atmospheric Research
OEI – operations efficiency index
OFCM – Office of the Federal Coordinator for Meteorology
OHPI – Office of Highway Policy Information
PIARC – World Road Association
PCB – professional capacity building
PFS – pooled fund study
PM – performance measure
R&D – research and development
RITA – Research and Innovative Technology Administration
ROI – return on investment
RW – road weather
RWIS – road weather information systems
RWM – road weather management
RWMP – Road Weather Management Program
SAFETEA-LU – Safe, Accountable, Flexible, Efficient, Transportation Equity Act - A Legacy for Users
SCOM – Subcommittee on Maintenance
SICOP – Snow and Ice Cooperative Program
SHRP2 – Strategic Highway Research Program 2
SOP – standard of practice or standard operational procedure
SWIW – spot weather impact warning
TOPS-BC – Tools for Operations Benefit-Cost
TRB – Transportation Research Board
TD – transportation department
TrEPS – traffic estimation and prediction system
UDOT – Utah Department of Transportation
U.S. – United States
USDOT – United States Department of Transportation
USGS – United States Geological Survey

LIST OF ABBREVIATIONS AND SYMBOLS (CONTINUED)

V2I – vehicle to infrastructure
VDT – vehicle data translator
VIIC – Vehicle Infrastructure Integration Consortium
VMT – vehicle miles traveled
VSL – variable speed limits
WDE – Weather Data Environment
WMTSP – Winter Maintenance Technical Service Program
WRTM – weather responsive traffic management
WSI – winter severity index

CHAPTER 1. INTRODUCTION

Since the Safe, Accountable, Flexible, Efficient, Transportation Equity Act - A Legacy for Users (SAFETEA-LU) legislation was passed in 2005, the Federal Highway Administration (FHWA) Road Weather Management Program (RWMP) had been involved in various programs, projects, and activities to help state and local agencies improve the performance of the transportation system during adverse weather conditions. Beginning in 2006, the RWMP has used a set of performance measures to gauge its success in achieving its goals which include improving national capacity for road weather management. Assessments of program performance were conducted and documented in 2009 and 2012.[1,2] The program has evolved over time, informed by past performance as measured by existing indicators and influenced by emerging trends in the field (e.g., Connected Vehicles). The RWMP continues to conduct a periodic review of its performance indicators to ensure that the performance measures reflect the changes in program objectives as well as the broader policy context. The *2015 Road Weather Management Performance Measures Survey, Analysis, and Report* project is the next iteration of this periodic review of the RWMP's performance, an update to the 2012 report.

Project Scope and Objectives

The 2015 update included a review of current RWMP objectives, activities, and products since 2012 to understand how the program has evolved in the last two years, and to identify the connection between these activities and RWMP's seven programmatic objectives and existing performance measures. In general, the reporting period for the performance update is 2012-2014 with some limited activities from 2015 included in the update. Additional performance measures were identified to better reflect new and emerging initiatives of the RWMP. Then, the updated list of measures was quantified as part of this effort. The sequence of tasks for this project is shown in Figure 1.

Figure 1. Illustration. Project Activities.

[1] Federal Highway Administration, *Road Weather Management Program Performance Metrics: Implementation and Assessment.* FHWA-JPO-09-061, 2009. Available at: http://ntl.bts.gov/lib/31000/31600/31611/14492_files/14492.pdf.

[2] Federal Highway Administration, *Road Weather Management Performance Measures – 2012 Update*. FHWA-JPO-13-87, 2013. Available at: http://ntl.bts.gov/lib/51000/51000/51065/26615E33.pdf.

Organization of Report

The remainder of the report is organized to reflect the progression of the project:

- *Chapter 2* summarizes the RWMP activities since 2012.
- *Chapter 3* highlights the new performance measures, updates to previously defined performance measures, and the methods used to quantify performance.
- *Chapters 4-11* provide an assessment of performance by RWMP objective.
- *Chapter 12* provides research conclusions.
- *Chapter 13* presents recommendations for future performance measure updates.

CHAPTER 2. ONGOING ROAD WEATHER MANAGEMENT PROGRAM ACTIVITIES

The first step in the performance measures update was to identify ongoing and new Road Weather Management Program (RWMP) activities since 2012. The list was compiled from a review of RWMP resources, including:

- Road Weather Management Program website (Available at: http://ops.fhwa.dot.gov/Weather/index.asp).
- United States Department of Transportation (USDOT) Road Weather Roadmap (Fiscal Years 2012-2017).
- Materials from the 2014 Road Weather Management Stakeholder Meeting (Available at: http://www.its.dot.gov/presentations.htm#road2014).
- *Road Weather Management Measures – 2012 Update* report (Available at: http://ntl.bts.gov/lib/51000/51000/51065/26615E33.pdf).
- Discussions with the Federal Highway Administration (FHWA) Road Weather Management Program staff.

In 2012, the RWMP identified seven programmatic objectives that guided the determination of program direction and activity. Slight modifications to objectives were recorded as part of a recent roadmap development activity to clarify the role of data and applications to the program. The current objectives of the program are provided below:

1. Build and sustain relationships with multi-disciplinary partners to expand RWM deployments.
2. Ensure road weather management investments improve highway performance.
3. (Advance) Transportation, weather, and research communities' use of and reliance on fixed and mobile road weather observations.
4. Advance the state of the art for mobile sensing and integrating vehicle data into road weather applications.
5. Advance the state of the practice by promoting tailored management strategies for different regions.
6. Improve integration of weather-related decision support technologies into traffic operations and maintenance procedures.
7. Advance the state of the practice by raising road weather capabilities and awareness across the transportation and weather communities.
8. Increase engagement of Operations community with climate change and sustainability communities.

The RWMP undertakes a variety of activities and projects to support the attainment of the listed objectives. The following sections describe the program activities that support the eight objectives.

Stakeholder Coordination

The RWMP has continued to support stakeholder coordination activities through workshops and other partnership-building activities. In recent years, the program's coordination covers a broader mix of stakeholders, building from a historical core of winter maintenance to new partnerships with connected vehicles, weather data, performance management, and traffic management. State departments of transportation (DOT) participation has held steady over the years, constrained by program budgets for participant travel.

The primary showcase for stakeholder engagement for the program is the annual meetings, which have been conducted since 2000. Initially, the annual meetings focused on maintenance decision support systems (MDSS), then on *Clarus*/MDSS, and now more broadly on road weather management. Three in-person meetings were conducted in the timeframe under review for this update (2012-2014). These regular meetings serve as a peer exchange for transportation and weather practitioners involved in road weather management from State DOTs, academia, vendors, and weather service providers. The topics vary from year-to-year, but typically include recent accomplishments, emerging ideas allowing for peer-to-peer sharing of best practices, and research initiatives. In 2015, a virtual road weather management meeting as conducted in lieu of an in-person workshop.

In addition to the RWMP stakeholder forum, a subset of stakeholders convened for weather responsive traffic management (WRTM) in 2013. Participants learned about real-world applications of WRTM and new research, tools, and resources available to support WRTM implementation. The stakeholders also helped identify gaps, challenges, and opportunities relating to WRTM strategies deployment.(3) The program continues to work with State DOTs to support real-world WRTM implementations.

In the reporting timeframe, the RWMP continued to leverage working relationships with various partners including:

- National Oceanic and Atmospheric Administration (NOAA).
- National Center for Atmospheric Research (NCAR).
- Office of the Federal Coordinator for Meteorology (OFCM).
- American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Maintenance (SCOM).
- AASHTO Snow and Ice Cooperative Program (SICOP).
- World Road Association (PIARC).
- Clear Roads Pooled Fund Program.
- Aurora Pooled Fund Program.
- American Meteorological Society (AMS) – Intelligent Transportation Systems (ITS) and Surface Transportation Weather Committee.
- National Weather Service (NWS).

[3] USDOT, Office of the Assistant Secretary for Research and Technology, ITS-JPO. "Road Weather - Second National Weather Responsive Traffic Management Stakeholder Meeting." Accessed October 1, 2015. Available at: http://www.its.dot.gov/road_weather/wrtm_stakeholder_meeting.htm.

- Transportation Research Board (TRB) – Surface Transportation, Winter Maintenance and other Committees.
- Intelligent Transportation Society of America.
- State DOTs.
- Traffic Management Center Pooled Fund Program.
- American Public Works Association (APWA).
- Institute of Transportation Engineers (ITE).

These partnerships are leading to important tangible accomplishments, such as the transition from *Clarus* to Meteorological Assimilation Data Ingest System (MADIS). Another example includes the Pathfinder project, which seeks to provide guidance on how the NWS, State DOTs, and the weather enterprise can develop mutually beneficial partnerships. Table 1 summarizes the key stakeholder coordination activities in this track during this time period.

Table 1. Stakeholder Coordination Activities.

Activity	Activity Description and Products/Results	Rationale for Inclusion in Performance Measurement	Short-Term Outputs	Long-Term Outcomes and Impacts
Road Weather Management (RWM) Stakeholder Meetings – 2012, 2013, 2014	Workshops support collaborative exchanges between all road weather stakeholders and allow for the sharing of best practices, products and services for RWM. Support the development of future research agenda of the RMWP	Continued growth in stakeholder participation directly supports program objectives #1 and #7	Information sharing and increased participation in RWMP research & development activities	Growth in the use of RWM technology, tools, and services
Weather Responsive Traffic Management (WRTM) Stakeholder Meetings, 2013	Workshops support collaborative exchanges between traffic management and road weather stakeholders and allow for the sharing of best practices, products, and services for WRTM	Continued growth in participation directly supports program objectives #5 and #7	Information sharing and increased participation in WRTM implementation	Improved traffic management capabilities during adverse weather

Table 1. Stakeholder Coordination Activities. (Continuation)

Activity	Activity Description and Products/Results	Rationale for Inclusion in Performance Measurement	Short-Term Outputs	Long-Term Outcomes and Impacts
RWMP Partnership Activities with pooled funds, TRB, ITS America, AASHTO, NWS, NOAA, OFCM, PIARC	Activities include support of mutual research and development efforts, outreach, workshop/seminar participation, guidance development, and funding support	Directly support program objective #1	Joint research activities and workshops/symposia development	Improved RWMP capabilities around the country
Pathfinder Project (Guidance on Partnerships)	Continued development of institutional partnership models to link NWS, DOT, and the weather enterprise. Evaluate current practices of State DOT interactions and relationships with the weather enterprise	Directly supports program objective #1	Pilots of new partnership approaches in regions	Sustained and stronger partnership between the three communities can lead to better RWM capabilities

AASHTO – American Association of State Highway and Transportation Officials
DOT – department of transportation
ITS America – Intelligent Transportation Systems of America
NOAA – National Oceanic and Atmospheric Administration
NWS – National Weather Service
OFCM – Office of the Federal Coordinator for Meteorology
PIARC – World Road Association
RWM – road weather management
RWMP – road weather management program
TRB – Transportation Research Board
WRTM – weather responsive traffic management

Program and System Performance Management

RWMP continues to support ongoing performance management of the program and the overall road weather management systems and practices in the country (Table 2). RWMP is continuing an assessment of the impact of weather on freight movement. The RWMP is also supporting a self-assessment tool for agencies or regions to identify actions for improving road weather management from an institutional perspective, building off the Strategic Highway Research Program 2 (SHRP2) Capability Maturity Models. The framework provides a structure for assessing current strengths and weakness and identifying targeted actions for improving capabilities. The program is also compiling benefit-cost analysis studies to further support continued growth in RWMP adoption.

Table 2. Program and Performance Measurement Activities.

Activity	Activity Description and Products/Results	Rationale for Inclusion in Performance Measurement	Short-Term Outputs	Long-Term Outcomes and Impacts
RWMP Compatibility Maturity Framework (CMF)	Development of an institutional capability maturity model	Directly supports objectives #2 and #7	Use of CMF tool to develop action plans at state or regional levels	Implementation of actions leads to improved RWMP capabilities around the country
RWMP Benefit-Cost Compilations	Make the business case for RWMP implementation	Directly supports objectives #2 and #5	Use of benefit-cost data by stakeholders	Demonstrate value of RWMP deployments to spur adoption by other State DOTs
Freight Delays due to Weather	Approach to quantify the delay to freight due to adverse weather	Directly supports objective #2	Freight delay costs are quantified and accepted by stakeholders	Agencies look for opportunities to collaborate with freight partners to mitigate delay
Operations Efficiency Index (OEI) Reporting Support	Assessment of road weather implementations in top-40 metropolitan areas conducted by FHWA division	Directly supports objectives #2 and #7	Identification of growth areas and gaps at metropolitan areas	Ability to tailor program products
Intelligent Transportation Systems – Joint Program Office (ITS-JPO) Benefit-Cost database and deployment tracking database support	Compilation of benefit cost studies and level of deployment of road weather management systems	Directly supports objective #2 and #7	Use of available benefit-cost studies by State DOTs to support investments	Benefit-cost data is supportive of greater adoption of RWM

Table 2. Program and Performance Measurement Activities. (Continuation)

Activity	Activity Description and Products/Results	Rationale for Inclusion in Performance Measurement	Short-Term Outputs	Long-Term Outcomes and Impacts
Tools for Operations Benefit-Cost (TOPS-BC) Analysis and WRTM	Create benefit-cost tools focused on road weather	Directly supports objectives #2 and #5	Improved modeling tools and analysis framework for WRTM	Agencies ability to model WRTM strategies is improved leading to better implementation

CMF – compatibility maturity framework
ITS-JPO – Intelligent Transportation Systems – Joint Program Office
OEI – operations efficiency index
RWMP – road weather management program
TOPS-BC – Tools for Operations Benefit-Cost
WRTM – weather responsive traffic management

Road Weather Research and Development – Data

In previous program performance updates, the *Clarus* program was the dominant research and development (R&D) effort in the area of road weather data. Activities focused on creating a national system of quality-checked sensor data from fixed road weather information systems (RWIS) operated by State and local agencies.(4) In 2013, the *Clarus* research ended and the system was turned off. NOAA is transitioning the road weather data network to MADIS and currently working with State DOTs to secure data sharing agreements.(5) To support the national research agenda, particularly the Connected Vehicle research initiative sponsored by the ITS-JPO, the *Clarus system* has been transitioned to Weather Data Environment (WDE), a research-oriented system of environmental sensor system (ESS) data.

Advancing the capability and use of RWIS continues to be an important element of the RWMP program. The program continues to participate in pooled fund efforts such as Clear Roads and Aurora to support greater standardization of RWIS, guidelines for RWIS installation and siting, and sensor improvements.

Research and development efforts in recent years have focused on developing new capabilities and tools to collect, process, and distribute mobile data (Table 3). The program has been an active participant in the ITS-JPO Real-Time Data Capture and Management program (DCM). The program's investments in this area for road weather management include the following activities:

4 Federal Highway Administration, *Road Weather Management Performance Measures – 2012 Update*. Available at: http://ntl.bts.gov/lib/51000/51000/51065/26615E33.pdf.
5 National Oceanic & Atmospheric Administration. "Data Access and Delivery Systems: Development Efforts." Accessed October 1, 2015. Available at: http://esrl.noaa.gov/gsd/isb/dads/developmentefforts/clarus.html.

- Vehicle data translator (VDT), a tool to translate mobile observations to usable weather/road weather data.
- Integrated mobile observations (IMO) program, which seeks to demonstrate the collection of mobile data from maintenance fleets for operations.
- Participation in Connected Vehicle Standards development from a road weather standpoint.

Table 3. Activities in Road Weather Research and Development Activities Related to Data.

Activity	Activity Description and Products/Results	Rationale for Inclusion in Performance Measurement	Short-Term Outputs	Long-Term Outcomes and Impacts
Weather Data Environment	Create a real-time research data set of fixed and mobile weather and road weather observations to support current and future application development	Directly supports objectives #3 and #4	A research environment for development of RWM applications	Lead to innovations in RWMP applications
Support *Clarus* Transition to MADIS	Support the transition to an operation-ready national observation system operated by NOAA	Directly supports objectives #3 and #4	*Clarus*/MADIS data sharing agreements are signed by various parties	A national observation system for road weather leads to better tools and services for RWM
IMO program	Research and demonstrate the value of mobile data collection from maintenance fleets. Demonstrate working systems in multiple states to spur innovation and adoption	Directly supports objectives #3 and #4	Demonstrations and Pilots of use-cases based on mobile data collection	Greater adoption and use of mobile data in RWM decision-making allows for better response during adverse weather

Table 3. Activities in Road Weather Research and Development Activities Related to Data. (Continuation)

Activity	Activity Description and Products/Results	Rationale for Inclusion in Performance Measurement	Short-Term Outputs	Long-Term Outcomes and Impacts
Vehicle Data Translator Development	Create a quality assurance tool to translate mobile data observations to useful weather/road weather information to support operations and application development	Directly supports objectives #3 and #4	A quality assurance tool to check mobile data and convert them to useful observations	Greater adoption and use of mobile data in RWM decision-making allows for better response during adverse weather
Standards Support (Connected Vehicles, NTCIP 1204, J2735 SE)	Development of consensus-based standards for road weather systems and applications especially in the context of connected vehicles	Directly supports objectives #3 and #4	Standards developed and adopted by agencies	Standards allow greater interoperability and seamless RWM nationally
Support Clear Roads Plug and Play Specifications	Support the growth and use of interoperable fixed road weather observation systems	Directly supports objectives #3 and #4	Specifications are drafted and adopted by State DOTs	Greater interoperability and ease of deployment lead to growth in use of systems for RWM
Prediction of Roadway Surface Conditions Using On-Board Vehicle Sensors	Determine and demonstrate if existing on-board vehicle sensors can be used to predict changing road friction	Directly support objectives #3	Model for predicting friction from on-board sensors	Greater use of mobile data in road surface condition monitoring

Table 3. Activities in Road Weather Research and Development Activities Related to Data. (Continuation)

Activity	Activity Description and Products/Results	Rationale for Inclusion in Performance Measurement	Short-Term Outputs	Long-Term Outcomes and Impacts
FHWA/ American Meteorological Society (AMS) Partnership on Open Data Environments	Ongoing activities to highlight need for and the importance of improved weather support for surface transportation through use of enhanced and open data sets	Directly support objectives #3	Stronger linkages between weather and transportation community regarding the issue of open data	Open data environments for improved weather and road weather forecasting

AMS – American Meteorological Society
DOT – department of transportation
FHWA – Federal Highway Administration
IMO – Integrated Mobile Observations
MADIS – Meteorological Assimilation Data Ingest System
NOAA – National Oceanic and Atmospheric Administration
NTCIP – National Transportation Communications for ITS Protocol
RWM – road weather management
RWMP – road weather management program

Road Weather Research and Development – Applications

Making systems management and operations-related decisions based on road weather observations and forecasts continue to be a challenge for many State and local agencies. In the previous update, program activities created a suite of decision-support tools using *Clarus* data. Since 2012, the emphasis has shifted to developing and demonstrating connected vehicle applications that use mobile data. The program has identified a roadmap to design, test, and develop applications related to Connected Vehicles and weather, with close linkages to the larger Connected Vehicle research program tracks like the Dynamic Mobility Applications (DMA) and Applications for the Environment: Real-Time Information Synthesis (AERIS). The development of this roadmap started with the *Vision for Use of Connected Vehicle Data in Practical Road Weather Applications* document completed by NCAR, which focused on the applications emerging from the use of vehicle data translator, and continued with the *Road Weather Connected Vehicle Application Scenario* document.

Activities under this track will create the next generation of applications and services that assess, forecast, and address the impacts weather has on roads, vehicles, and travel, and develop algorithms and capabilities to translate mobile data into usable weather and road condition observations. Currently, the RWMP is supporting several development efforts for the Vehicle to Infrastructure (V2I) track including:

- Developing the Motorists Advisories and Warnings (MAW) application which uses Connected Vehicle data to provide road weather advisories and warnings in near real time.
- Supporting the development of spot weather impact warning (SWIW) applications for commercial vehicles.
- Developing an Enhanced Maintenance Decision Support System (EMDSS). The MDSS initiative transitioned from research to implementation activities led by State and Local agencies. Current enhancements include integrating connected vehicle data with prototype MDSS to provide spot specific road weather forecasts and recommendations.
- Supporting a benefit-cost analysis for connected vehicle applications to estimate potential national costs and benefits resulting from the implementation of connected vehicle applications.

Table 4 lists the new activities in this area since 2012.

Table 4. Road Weather Research and Development Related to Applications.

Activity	Activity Description and Products/Results in this Time Period	Rationale for Inclusion in Performance Measurement	Short-Term Outputs	Long-Term Outcomes and Impacts
Vision for Use of Connected Vehicle (CV) Data	Developed vision for weather applications based on connected vehicle data	Directly supports objectives #4	Broader awareness of CV applications for RW	Road Weather V2I applications are implemented widely
Road Weather Connected Vehicle Applications Scenarios/Use-Case Development	Established near-term use-cases and scenarios for development	Directly supports objectives #4	Broader awareness of CV applications for RW	Road Weather V2I applications are implemented widely
Road Weather Connected Vehicle Safety Benefits	Created a business case for development of road weather applications	Directly supports objectives #4	Broader awareness of CV applications for RW	Road Weather V2I applications are implemented widely

Table 4. Road Weather Research and Development Related to Applications. (Continuation)

Activity	Activity Description and Products/Results in this Time Period	Rationale for Inclusion in Performance Measurement	Short-Term Outputs	Long-Term Outcomes and Impacts
Participation in V2I Application Development Efforts	Demonstrate and prototype V2I deployment applications for road weather. Currently a variety of applications are being pursued as part of this effort including EMDSS, MAW, and SWIW	Directly supports objectives #4	Broader awareness of CV applications for RW	Road Weather V2I applications are implemented widely
Participation in V2I Application Deployment Guidance	Continue to provide state and local agencies with clear guidance on how V2I technologies can be used for mitigating adverse weather impacts	Directly supports objectives #4	Broader awareness of CV applications for RW	Road Weather V2I applications are implemented widely

CV – connected vehicle
RW – road weather
V2I – vehicle to infrastructure

Weather-Responsive Traffic Management

Weather-Responsive Traffic Management (WRTM) strategies support the ability of agencies to provide travelers with safe and reliable traffic conditions 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 the past two years, the program has supported six implementation projects of innovative WRTM practices in Utah, Wyoming, Michigan, Oregon, and South Dakota. The following WRTM strategies are being implemented in the States:

- Citizen Reporters to improve road condition reporting and traveler information (Utah DOT).
- Weather Responsive Traffic Signal Control (Utah DOT).
- Weather Responsive Active Transportation Management (Oregon DOT).
- Mobile application-reported data from snow plows for traffic management and traveler information (Wyoming DOT).
- MDSS data to augment road condition reporting systems and traveler information (South Dakota DOT).
- Mobile data from vehicle fleets to support traveler information (Michigan DOT).

To support continued growth in WRTM adoption, the program is investing in analysis, modeling, and simulation (AMS) tool development. Activities relating to AMS include projects to support State-level testing and implementation of Traffic Estimation and Prediction System (TrEPS), development of integrated road condition modeling system concepts, as well as participation in the Active Transportation Demand Management (ATDM) test beds. Another activity promoted by the program in this track relates to messaging guidelines for State and local agencies to use during adverse weather. Table 5 lists the activities for the WRTM initiative.

Table 5. Weather-Responsive Traffic Management Program Activities.

Activity	Activity Description and Products/Results	Rationale for Inclusion in Performance Measurement	Short-Term Outputs	Long-Term Outcomes and Impacts
WRTM Implementation and Evaluation Support	Support WRTM deployments in five States	Directly supports objective #5	Implementation and evaluation of innovative WRTM concepts	Demonstrate value of WRTM deployments to spur adoption by other State DOTs
Messaging Guidelines for Road Weather	Promote consistent messaging of weather and road conditions nationally	Directly supports objectives #2 and #5	Adoption of messaging guidelines by State DOTs	Improve consistent messaging across the nation during adverse weather
Support ATDM/DMA Test Bed Development	Develop an analytical capability to test, verify, and compare WRTM strategies especially emerging strategies such as Active Traffic Management (ATM); this testbed will also support testing of dynamic mobility applications	Directly supports objectives #2 and #5	Improved modeling tools and analysis framework for WRTM	Agencies ability to model WRTM strategies is improved leading to better implementation

Table 5. Weather-Responsive Traffic Management Program Activities. (Continuation)

Activity	Activity Description and Products/Results	Rationale for Inclusion in Performance Measurement	Short-Term Outputs	Long-Term Outcomes and Impacts
Support TrEPS deployment	Use TrEPS in both off-line and on-line setting for road weather management	Directly supports objectives #2 and #5	Improved modeling tools and analysis framework for WRTM	Agencies ability to model WRTM strategies is improved leading to better implementation

ATDM – active transportation and demand management
DMA – dynamic mobility application
TrEPS – traffic estimation and prediction system
WRTM – weather responsive traffic management

Technology Transfer, Training, and Education

Providing training, education, technical assistance, technology transfer, and resources to assist RWM practitioners in State DOTs and other transportation agencies to more fully consider weather in their management and operational responsibilities has been an important component of the RWMP since its inception. The RWMP has produced and made available through its website various outreach documents, technical reports, and papers. In 2012, the program broadened this objective to focus on expanding and strengthening the range of road weather capabilities throughout the transportation industry. The RWMP is also beginning a knowledge and technology transfer (KTT) activity that will coordinate various outreach and training efforts conducted in future years.

The RWMP website continues to be the primary information outlet for technology transfer. The following documents were published on the website from 2012-2015:

- Road Weather Management Best Practices: Version 3.0, 2012.
- The Vision for Use of Connected Vehicle Data in Practical Road Weather Applications, 2012.
- Use of Mobile Data for Weather Responsive Traffic Management Models, 2012.
- Guidelines for the Use of Variable Speed Limit Systems in Wet Weather, 2012.
- Implementation and Evaluation of Weather Responsive Traffic Estimation and Prediction, 2012.
- Guidelines for Disseminating Road Weather Advisory and Control Information, 2012.
- Weather Delay Costs to Trucking, 2012.
- Road Weather Management Best Practices: Version 3.0, 2012.
- Road Weather Management Performance Measures: 2012-2013.
- Results from the Integrated Mobile Observations Study, 2013.
- Concept of Operations for Road Weather Connected Vehicle Applications, 2013.
- Planning for Systems Management & Operations as part of Climate Change Adaptation, 2013.

- Utah DOT Weather Responsive Traffic Signal Timing, 2013.
- Utah DOT Weather Responsive Traveler Information System, 2013.
- Utah DOT Citizen Reporting Program for Road Weather, 2013.
- Weather Responsive Traffic Signal Timing at Utah DOT, 2013.
- Guidelines for Disseminating Road Weather Messages—Improved Road Weather Information for Travelers, 2013.
- Implementation of a Weather Responsive Traffic Estimation and Prediction System (TrEPS) for Signal Timing at Utah DOT, 2014.
- Traffic Signal LED Module Specification Workshop and Informational Report for Snow Conditions, 2014.
- The Road Weather Management Benefit Cost Analysis Compendium, 2014.
- Citizen Reporting of Current Road Conditions – Experiences at Five State Departments of Transportation, 2015.

The Consortium for ITS Training and Education (CITE) at the University of Maryland helps the RWMP deliver three instructor-led, web-based ("blended") courses and online, independent study courses on Road Weather Management. The "Principles and Tools for Road Weather Management" course offers participants training on various strategies for addressing road weather problems, including RWIS and the development of cross-cutting decision support systems to respond effectively to weather situations. The "Weather Responsive Traffic Management" course provides participants with an understanding of the strategies, data types, analysis tools, and performance monitoring necessary to effectively manage traffic during weather events. Two deliveries of this course occurred in 2013. 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.[(6)] Since the fall of 2010, this course has been offered four times and has had consistent registration numbers. CITE now offers a certificate course in Road Weather Management to participants who have taken all three courses described above and an additional ITS-related course from their catalog. This certificate program began in 2013, and the number of participants attaining the certificate needs to be tracked in future years as part of the knowledge and technology transfer activity.

The RWMP continues to offer additional webinars through the ITS Professional Capacity Building (ITS PCB) program. From 2012 to 2014, the program offered the following webinars:

- Managing Traffic during Flood Events: Transportation Agency Experiences and Strategies.
- Performance Measures and Benefit-Cost Analysis for Weather Responsive Traffic Management.
- Connected Vehicle Reference Implementation Architecture (CVRIA) Webinar #3: Road Weather.
- Road Weather Management Best Practices.

[6] Consortium for ITS Training and Education, "Road Weather Information Systems (RWIS) Equipment and Operations (Blended)." Accessed October 1, 2015. Available at: http://www.citeconsortium.org/course/road-weather-information-systems-rwis-equipment-and-operations-blended/.

- Active Traffic Management (ATM) and Weather.
- Benefit-Cost Tools for Weather Responsive Traffic Management.

RWMP training, education opportunities, and technical transfer activities are shown in Table 6.

Table 6. Training, Education, and Technical Transfer Activities.

Activity	Activity Description and Products/Results	Rationale for Inclusion in Performance Measurement	Short-Term Outputs	Long-Term Outcomes and Impacts
Research Reports, Publications on RWM Websites	Dissemination of current research products, services, and guidelines through FHWA Operations website	Directly supports objective #7	Website becomes a go-to resource for road weather information	Support stakeholder needs for RWM capability improvement
RWM Training Courses	Certificate course on RWM for State and local agencies comprising of three courses which can also be taken separately	Directly supports objective #7	Continued use of training tools creates a critical mass of RWM experts	Support stakeholder needs for RWM capability improvement
RWM Webinars	Six webinars on best practices and peer information on emerging topics for RWM	Directly supports objective #7	Share best practices between agencies	Support stakeholder needs for RWM capability improvement

FHWA – Federal Highway Administration
RWM – road weather management

Operations, Climate Change, and Sustainability

In the previous update, the program began the process of coordinating with climate change and sustainability stakeholders including helping define the Operations and Maintenance measures in the Infrastructure Voluntary Evaluation Sustainability Tool (INVEST), particularly with respect to snow and ice control. INVEST continues to be promoted by FHWA. Through work with the TRB committees and the pooled funds, the program supported the greater consideration of sustainability within the maintenance community, especially with respect to snow and ice control. Following these efforts, the program continues to work with partners and is currently developing a primer for climate change adaptation strategies, particularly in response to extreme weather. RWMP has also been supporting national workshops and symposia on the subject of extreme weather and climate change, as illustrated in Table 7.

In 2013 and 2014, the program supported AASHTO's efforts to engage stakeholders around the topic of extreme weather.[7,8] The program expects to continue supporting activities to mitigate the impact of extreme weather in 2015 by working with AASHTO and TRB. In 2015, the program will participate in at least two TRB conferences on sustainability and resilience.

Table 7. Activities Related to Linking Climate Change and Environment and Road Weather Management.

Activity	Activity Description and Products/Results	Rationale for Inclusion in Performance Measurement	Short-Term Outputs	Long-Term Outcomes and Impacts
Support of INVEST Tool and Pilot Locations	RWMP promotes the testing and use of INVEST tool to improve sustainability of road weather operations	Directly supports objective #8	Greater awareness of road weather role in sustainability	Adoption of sustainable road weather practices
Development of a Primer on Climate Change Adaptation/ Sustainability Guide	Development of a primer to compile the list of climate-sensitive decisions and adaptation strategies for transportation systems management and operations, especially as it relates to extreme weather	Directly supports objective #8	Greater awareness of climate-sensitive decisions and risk to operations agencies	Inclusion of climate change considerations in planning for operations
Support to Workshops and Symposiums on this Topic	Sessions and presentations on the role of road weather management for extreme weather	Directly supports objective #8	Generate awareness around the topic of extreme weather management	Improve extreme weather management

INVEST – Infrastructure Voluntary Evaluation Sustainability Tool
RWMP – road weather management program

[7] Center for Environmental Excellence by AASHTO, "2013 Extreme Weather Events Symposium." Accessed October 1, 2015. Available at: http://environment.transportation.org/center/products_programs/conference/2013_extreme_weather_symposium.aspx.

[8] Center for Environmental Excellence by AASHTO, "2014 Extreme Weather Sessions." Accessed October 1, 2015. Available at: http://environment.transportation.org/center/products_programs/conference/2014_extreme_weather_sessions.aspx.

CHAPTER 3. CHANGES IN PERFORMANCE MEASURES

This chapter describes the changes to the performance measures reported in 2012. These changes are necessary to address gaps in performance measurement due to current program objectives and activities and recent advances in capability and technology for road weather management.

Gaps In Performance Measurement

Based on the current inventory of program activities, the team identified gaps in the previous performance measurement framework. Some of these gaps are described below.

Extent of Use and Adoption of Mobile Data-based Applications

Since the previous update, the Road Weather Management Program (RWMP), as part of the Connected Vehicle Research track, has been supporting the development of Vehicle to Infrastructure (V2I) applications that leverage mobile data and vehicle to infrastructure connectivity to support road weather management. Currently, the RWMP is supporting several development efforts for V2I applications including the Motorist Advisories and Warnings (MAW), Spot Weather Impact Warning (SWIW) applications for commercial vehicles, Enhanced Maintenance Decision Support Systems application (EMDSS). The WRTM program is also supporting several applications that use mobile data and remote connectivity in Wyoming, South Dakota, and Michigan. The aforementioned V2I applications are in research phases, and agencies' involvements in these efforts are captured through the research and development (R&D) performance measure. However, a gap remains in understanding how V2I and mobile data are being used by the States.

Climate Change/Extreme Weather/Resilience

The stakeholder community has expressed a great interest in managing extreme weather and improving the resiliency of operations, and the program has supported various stakeholder engagement activities on this topic through the American Association of State Highway and Transportation Officials (AASHTO) and Transportation Research Board (TRB). Currently, the program has not identified performance measures that effectively assess growth in this area at the State departments of transportation (DOT) and local levels. Research and guidance development is ongoing in this area but is still in early stages.

Section 1201 Rule Compliance

In 2015, State DOTs began reporting road condition data in compliance with the Section 1201 rule for appropriate areas and segments. While the rule does not specify how compliance should be achieved or the methods to report data, monitoring the self-reported rate of compliance with the rule requirements is a good measure to track timeliness of road condition availability in the nation.

Meteorological Assimilation Data Ingest System Transition

With the sunset of the *Clarus* program, the RWMP has been supporting the transition of the fixed and mobile Environmental Sensor Stations (ESS) data maintained by State DOTs to Meteorological Assimilation Data Ingest System (MADIS). The program is supporting the signing of data sharing agreements between State DOTs and National Oceanic and Atmospheric Administration (NOAA) and the integration of *Clarus* quality-checking algorithms into MADIS. To ensure the broad national scope of *Clarus* is transitioned, it is important for the program to track how many States are now connected to MADIS.

Expanding Partnerships

Starting with primarily the maintenance groups within State DOTs and a select group of weather/meteorological experts, the program has expanded its reach over the past decade to operations, technology, private sector, and the broader weather enterprise. While participation in stakeholder meetings is tracked, there is no performance measure that tracks the growth in partnerships as evidenced by the new groups involved in road weather management. For example, representatives from universities, private sector information service providers (e.g., Inrix, Waze), and connected vehicle experts have participated in recent stakeholder meetings.

Mainstreaming of Road Weather Management Programs

Throughout the past decade, an emphasis of the program has been to mainstream road weather management as a core function of State DOTs. Supporting this desire is the recent engagement in the institutional capability maturity framework development and deployment for road weather management.

Performance Measurement/Continuous Improvement of Road Weather Management Programs

The role of performance measurement continues to grow through both Federal and State initiatives. The Moving Ahead for Progress in the 21st Century Act (MAP-21) requires a greater consideration of performance in transportation investments, and States are looking at ways to maximize the return on investment of their limited resources. Higher traveler expectations are also fueling the increased use of performance measures to gauge agency performance. Currently, there are no measures that document the extent of use in collecting and reporting performance measures by the State DOTs.

Updated Performance Measures for 2015

Table 8 lists the measures that were identified as candidates for inclusion in the 2015 performance measures update. A total of 27 measures are tracked. Seven new measures have been added since the last update in 2012. One measure has been deleted, and the wording/definitions of four measures have been revised. With the exception of Objective 4, there

are multiple performance measures associated with all objectives of the program. New measures are highlighted in **bold** within the table.

Table 8. Updated Performance Measures for 2015.

Objective 1: Build and sustain relationships with multi-disciplinary partners to expand road weather management deployments
PM #1: Number of agencies participating in road weather R&D projects
PM #2: Number of agencies participating in, and benefiting from, road weather management stakeholder meetings/workshops
Objective 2: Ensure road weather management investments improve highway performance
PM #3: Number of agencies that collect and report road weather-related performance measures to the public (i.e. winter severity index, mobility index, etc.)
PM #4: Number of agencies that have a process for evaluating the ROI or net benefit of their road weather management investments
PM #5: Reductions in agency costs of weather-related maintenance and operations activities
PM #6: Reduction in number and types of fatalities and crashes attributed to adverse weather nationally
PM #7: Reduction in the extent of capacity losses and delays due to fog, snow, and ice events including freight
PM #8: Increase in travel time reliability or decrease in variability due to road weather management strategies during adverse weather scenarios
PM #9: Reduction in the number of tons of salt or chemical usage in the U.S. normalized by Winter Severity Index
Objective 3: (Advance) Transportation, weather, and research communities' use of and reliance on fixed and mobile road weather observations
PM #10: Number of State DOTs that are participants in the MADIS program
PM #11: Number of State DOTs that subscribe to road weather products and services
PM #12: Number of State DOTs collecting mobile observations of road weather data from appropriate vehicle fleets
PM #13: Number of State DOTs reporting the use of ESS in operations and maintenance activities
Objective 4: Advance the state-of-the-art for mobile sensing and integrating vehicle data into road weather applications
PM #14: Number of/percentage of responding agencies using mobile data-based applications in road weather management

Table 8. Updated Performance Measures for 2015. (Continuation)

Objective 5: Advance the state-of-the-practice by promoting tailored management strategies for different regions
PM #15: Number of States disseminating weather advisory and other road weather information to travelers
PM #16: Number of agencies using control and treatment strategies during weather events
PM #17: Number of agencies that have participated in or conducted RWM capability maturity assessment exercises
PM #18: Number of agencies that coordinate with their local forecast offices for road weather management and operations
Objective 6: Weather-related decision support technologies are integrated into traffic operations and maintenance procedures
PM #19: Number of agencies adopting MDSS technologies and methods
PM #20: Number of agencies using other weather-related decision-support tools
PM #21: Number of agencies reporting use of appropriate analysis tools to factor weather impacts and strategies
Objective 7: Advance the state-of-the-practice by raising road weather capabilities and awareness across the transportation and weather communities
PM #22: Number of agencies and attendees who have taken any of the training courses and workshops sponsored by the RWMP
PM #23: Number of agencies and participants in road weather management webinars led by the RWMP
PM #24: Number of meetings, site visits or venues where road weather management presentations/briefings were made
PM #25: Number of hits/visits to RWMP websites
Objective 8: Operations community is engaged with climate change & sustainability communities
PM #26: Number of public agencies meeting sustainability criteria related to road weather management
PM #27: Number of agencies conducting vulnerability/risk assessments, developing/implementing resiliency plans or adaptation plans, for their road weather management infrastructure and processes to respond to climate change and extreme weather
DOT – department of transportation ESS – environmental sensor station MADIS – Meteorological Assimilation Data Ingest System MDSS – maintenance decision support systems PM – performance measure R&D – research and development ROI – return on investment RWM – road weather management RWMP – road weather management program

Quantifying Measures

Each of the 27 measures was quantified during this update using a variety of data sources. Conducting the performance measure update requires collecting data available in 2015 from multiple sources on the specific RWMP activities and the broader impact of road weather management efforts.[9] There are four main sources that provide data for the RWMP performance measures:

- RWMP Records - The depth and breadth of the RWMP's research, training, and engagement activities are documented in RWMP records—these data demonstrate the reach and impact of the RWMP.
- State DOT Survey - One of the key data sources used in the previous updates was a targeted survey of State DOTs, which compiled data on the current levels of RWM deployment and capabilities around the country. For the 2015 update, a brief online survey was distributed to representatives at 49 State DOTs (all States except Hawaii). The survey was completed by 52 respondents from 40 states (an 82% response rate), comprised of almost all the winter-weather states. Figure 2 below illustrates the distribution of the survey respondents.
- Literature Reviews and Internet Searches - Peer-reviewed literature and Pooled Fund Studies (PFS) provide additional data for the performance measure update especially as it pertains to data regarding system outcomes and specific case studies/evaluation of road weather management strategies.
- Additional Data Sources - Other data resources are used to supplement the primary sources listed above to meet the data requirements for the performance measurement update. These include the Intelligent Transportation Systems (ITS) Deployment Statistics, ITS Benefit-Cost Database, and the FHWA Operations Efficiency Index (OEI). In many cases, these data elements will be used to support the findings for the performance measures.

[9] The data request period is 2013-2015, except in cases where data were not available for 2011-2012 during the last performance measure update, in which case older data will also be collected.

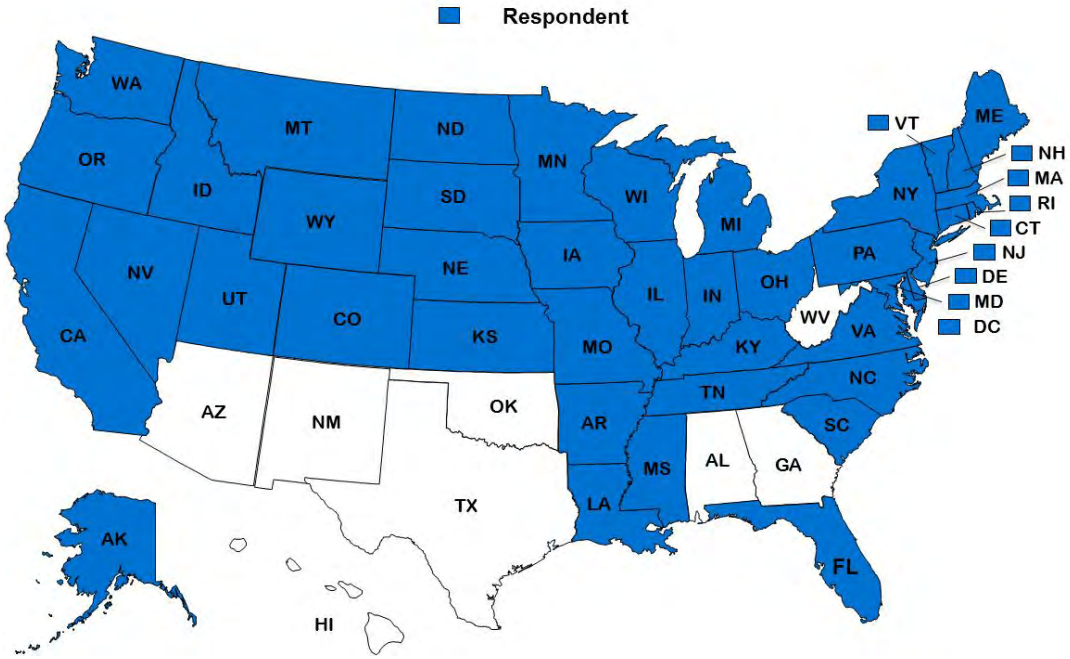

Figure 2. Chart. Map of the 2015 State Survey Respondents (shown in blue).

Assumptions, Challenges, and Constraints

The performance measures are crafted to reflect the changes to the current program and broader road weather management context, yet limitations arise particularly relating to data availability and the ability to isolate independent impacts. The following assumptions and limitations should be noted:

- The main assumption underlying the use of these performance measures is the State DOT as the unit of measure for data collection. While State DOTs represent the primary stakeholders for the RWMP, there are other entities involved in the implementation of road weather management. The involvement of these other agencies in the data collection is limited, but will be highlighted and quantified where possible.
- Additionally, while some significant impacts are highly attributable to the RWMP programs, projects, and activities, some aspects of the program's goal attainment may result from indirect impact channeled through other national efforts (e.g., AASHTO, Pooled Funds, etc.) that operate within the realm of road weather management. Therefore, it is a challenge for performance measurement to entirely isolate and measure the independent impacts attributable to the RWMP from aggregate impacts that are contributing to goal attainment.
- The State DOT survey is developed to maximize comparability for the measures used in previous updates by replicating wording used in prior surveys. However, changes in survey methodology and reporting that occur with external data sources make comparability a challenge—this is particularly true with other survey sources such as ITS Deployment Statistics and the OEI.

- The lack of widely accepted performance measures and methods for evaluating winter maintenance activities across the nation makes regional comparisons difficult especially at the outcome level.

Performance Results

The following sections provide results for each of the twenty-seven measures organized by the eight objectives. A short summary across the objective is also provided.

CHAPTER 4. OBJECTIVE 1: BUILD AND SUSTAIN RELATIONSHIPS WITH MULTI-DISCIPLINARY PARTNERS TO EXPAND ROAD WEATHER MANAGEMENT DEPLOYMENTS

Partnerships with State departments of transportation (DOTs) and local agencies are critical to implementing the Road Weather Management Program's (RWMP) research agenda for road weather management. The RWMP encourages transportation agencies to participate in demonstrations and pilot projects for a number of innovative road weather research areas, including fostering cross-entity collaboration to coordinate road weather messaging for travelers; developing a nationwide network of environmental sensor stations (ESS) to provide web-based accessibility to real-time data for atmospheric and pavement observations; and advancing the use of vehicle sensor technology to collect data about atmospheric and pavement conditions. This objective includes two performance measures (PM) that assess the breadth and depth of RWMP's stakeholder engagement.

PM #1: Number of agencies participating in road weather Research and Development projects

This performance measure captures the extent to which State and local transportation agencies are participating in research and development (R&D) projects initiated by the RWMP. These R&D activities encompass all major initiatives of the RWMP, including the Pathfinder Project, RWMP Capability Maturity Framework (CMF), Weather Data Environment, Integrated Mobile Observations (IMO) Program, Vehicle to Infrastructure (V2I) Application Development Efforts, and weather responsive traffic management (WRTM) implementation support activities. R&D demonstration projects involving agency participation provide direct benefits to the agencies through staff involvement. The continued involvement of agencies is a direct testament to their perceived benefit of the RWMP R&D efforts. Table 9 lists public agencies that participated in a significant manner in R&D efforts between 2012 and 2014 and includes activities where the agency was a RWMP grant recipient. In many cases listed, these agencies contribute matching funds or in-kind resources (e.g., staff time) to participate in these projects.

Table 9. List of State Departments of Transportation Participating in Road Weather Management Program Research and Development Efforts.

Research Activity	Public Agencies Directly Involved in Road Weather Management Program Research and Development
Pathfinder Project	California DOT, Nevada DOT, Utah DOT, and Wyoming DOT
RWMP Capability Maturity Framework	Alaska DOT, City of Fargo (North Dakota), Colorado DOT, Nevada DOT, New Hampshire DOT, Idaho DOT and Wyoming DOT
Weather Data Environment	Alaska DOT & PF, Arizona DOT, Colorado DOT, Delaware DOT, Idaho TD, Illinois DOT, Iowa DOT, Kansas DOT, Kentucky TC, Michigan DOT, Minnesota DOT, Missouri DOT, Montana DOT, Nevada DOT, New Hampshire DOT, New Jersey DOT, New York DOT, North Dakota DOT, Oregon DOT, Texas DOT, Vermont AOT, Virginia DOT, Wisconsin DOT, Wyoming DOT

Table 9. List of State Departments of Transportation Participating in Road Weather Management Program Research and Development Efforts. (Continuation)

Research Activity	Public Agencies Directly Involved in Road Weather Management Program Research and Development
IMO Program	Michigan DOT, Minnesota DOT, and Nevada DOT
WRTM Implementation Support Activities	Michigan DOT, Oregon DOT, South Dakota DOT, Utah DOT and Wyoming DOT
V2I Implementation Activities – Performance Measurement Prototype	Vermont AOT, New Hampshire DOT, Idaho TD, Iowa DOT, Michigan DOT, Nevada DOT, Minnesota DOT
V2I Implementation Activities – Motorist Alerts and Warnings	Michigan DOT, Minnesota DOT, Nevada DOT
V2I Implementation Activities Enhanced Maintenance Decision Support System	Michigan DOT, Minnesota DOT, Nevada DOT

DOT – department of transportation
IMO – integrated mobile observations
RWMP – road weather management program
TD – transportation department
V2I – vehicle to infrastructure

Since the 2012 report, the breadth and depth of State DOT involvement in RWMP activities has slightly increased. In the previous update, eleven States did not participate in any activity, whereas, in this update that number fell slightly to ten. As seen in the previous update, higher levels of participation are seen from States in the Northwest, Midwest, and New England regions where adverse weather is significant issue.

PM #2: Number of agencies participating in and benefiting from road weather management stakeholder meetings/workshops

Beginning in 2000, RWMP has held regular stakeholders meetings, focusing initially on maintenance decision support systems (MDSS) and later *Clarus*/MDSS. Since 2009, the meetings have focused more broadly on road weather management. Now these meetings include annual RWMP stakeholder meetings and WRTM meetings held every two years. This performance measure tracks State participation in these meetings and monitors the continued interest and growth of the RWM stakeholder community. The data are compiled from RWMP meeting records.(10) State participation in stakeholder meetings increased steadily until 2012, where it peaked with 36 states attending the RWMP meeting. Since then, State DOT attendance at the annual RWMP meetings has decreased with more than a 50 percent reduction over two years with 16 State DOTs participating in 2014, as indicated in Figure 3.

[10] In addition to States, other private and public agencies attend the stakeholder meetings. These agencies are not included in the measure, as this level of detail is not available for the earlier *Clarus*/MDSS meetings.

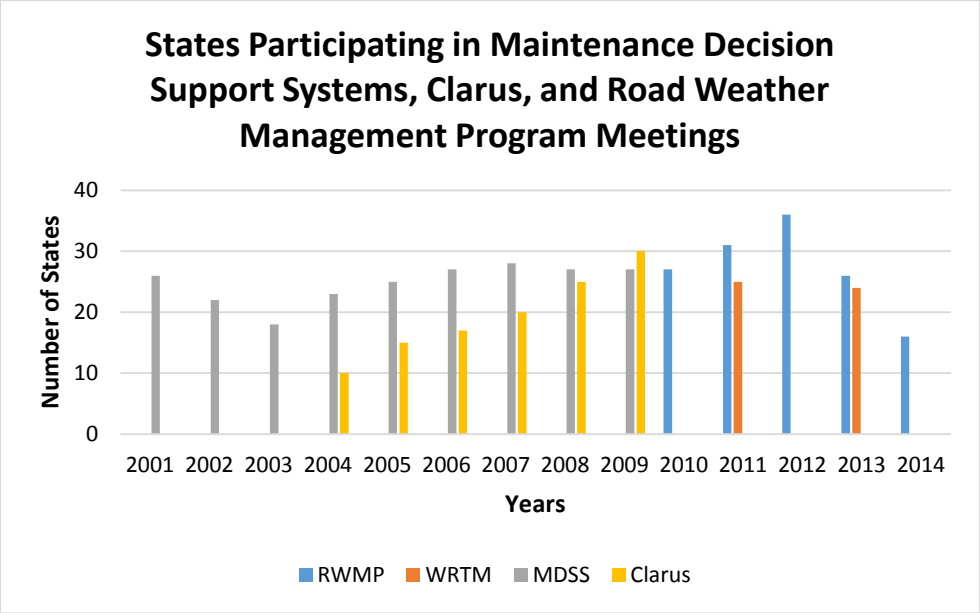

Figure 3. Graph. State Participation in Stakeholder Meetings Organized by Road Weather Management Program.

Continuing funding constraints and travel restrictions at State DOTs are increasingly making it difficult to attend stakeholder meetings. However, note that the overall attendance in Stakeholder workshops is increasing with a greater proportion of private sector attendees, as shown in Table 10. Evaluations from the meetings and workshops show very positive feedback from the attendees. An overwhelming majority of participants expressed that the meetings and workshops met or exceeded their expectations and provided information that is useful and relevant to their duties.

Table 10. Participation by Type in Road Weather Management Program Stakeholder Meetings in 2012, 2013, and 2014.

Attendance by Type	2012	2013	2014
A - Academia	7	8	1
C - Consultant	15	17	19
D – State Departments of Transportation	37	61	54
F - Federal government	9	10	15
I - International Public Sector	0	0	1
L - Local Agency	3	2	1
V – Vendor	12	20	34
Total	**83**	**118**	**125**

Summary

Overall, the two performance measures reveal strong engagement, with partnerships fostered and supported by the RWMP. State DOT participation in RWMP R&D continues to grow with the largest number of State DOTs involved in transitioning the *Clarus* system to the Weather Data

Environment. However, other R&D efforts such as WRTM, V2I implementation support have also included effective partnerships with State DOTs. The stakeholder meetings continue to be a valuable and growing forum for information exchange in the road weather management community evolving over time from *Clarus* and MDSS focused meetings to a broader road weather management agenda. With growing challenges in supporting in-person meetings and travel constraints at State DOTs, maintaining participation of public agencies is a challenge. In an effort to reduce costs and increase the level of participation, the RWMP transitioned the 2015 annual meeting from an in-person meeting to a virtual meeting.

CHAPTER 5. OBJECTIVE 2: ENSURE ROAD WEATHER MANAGEMENT INVESTMENTS IMPROVE HIGHWAY PERFORMANCE

Through implementation of various activities, products, and services supported by the Road Weather Management Program (RWMP) and growing capabilities at State and local agencies, meaningful improvements in highway performance are expected nationally during adverse weather conditions. The following six performance measures (PM) are used to monitor progress and performance to identify how program activities are contributing to overall performance of the highway system.

PM #3: Number of agencies that collect and report road weather-related performance measures to the public

Collecting and reporting road weather-related performance measures to the public enhances State departments of transportation (DOT) transparency. Conveying the effectiveness and efficiency of road weather management (RWM) activities can be a valuable public relations tool for the agency, helping the public better understand how public funds are spent on these types of activities. Reporting may include dashboards, winter maintenance reports, seasonal summaries, etc.

Different performance measures for snow and ice control have been used in the United States and abroad with varying degrees of success, but it is difficult to establish widely accepted standards of success applicable to different roadway classifications, storm characteristics, traffic conditions, or even location. The lack of widely accepted standards for measuring success of snow and ice control activities has been a long-standing concern and challenge for the winter maintenance community for the following reasons:

- Every storm or winter event is different in terms of the responses acted upon and the roadway conditions encountered. For example, two snow events in one location with the same levels of precipitation but at different times of day (e.g., rush hour versus non-rush hour) have very different outcomes. In other words, the pathway to link the inputs, activities, outputs, outcomes and impacts of maintenance actions is complex and varies greatly.
- The geographic and temporal variation of events presents a significant challenge to compare and contrast performance across regions within and outside jurisdictions. The same storm event might have significant impacts on a portion of the region while leaving others unscathed.
- Winter severity varies from season to season. In the absence of a consistent method/index to normalize, existing performance assessments fail to account for seasonal variations.
- The diversity of agencies and contractors involved in winter weather makes it difficult to establish a consistent set of measures. Each agency generally determines its own levels of service, often driven by their customers and the roads they are maintaining. Expectations and practices can vary greatly between a small local agency and a State DOT or toll authority. Available budgets also drive the types of equipment used, the levels of staffing, and the response plans that ultimately determine performance. Challenges between in-

house operations and contracted operations create additional challenges in establishing consistent performance measures.

In spite of these challenges, many State and local agencies have developed approaches to measure performance for snow and ice control. Starting with measures that focus on maintenance inputs and outputs, agencies have started to develop measures using data from field reports, maintenance management systems, and traffic operations to improve their operations. This has led to a patchwork of measures that are defined and used in an ad-hoc manner at an agency level.

Among the State DOTs surveyed, 23 DOTs (58%) reported regularly collecting and reporting some form of road weather performance measures. Eight States reported they did not collect and report road weather performance measures, and eight respondents were uncertain. Unfortunately, the responses to the survey did not provide more detail on the nature of the performance assessment conducted by the 23 States.

PM #4: Number of agencies that have a process for evaluating the return on investment or net benefit of their road weather management investments

Evaluating return on investment (ROI) is a management process State DOTs can use to evaluate the effectiveness of road weather measurement activities. The majority of States reported that they did not have a process or were not sure regarding evaluating ROI or the net benefits of road weather management investments. Out of the respondents, five agencies do have a process in place. Figure 4 shows the number of State DOTs that have a process for evaluating ROI or net benefits of RWM investments.

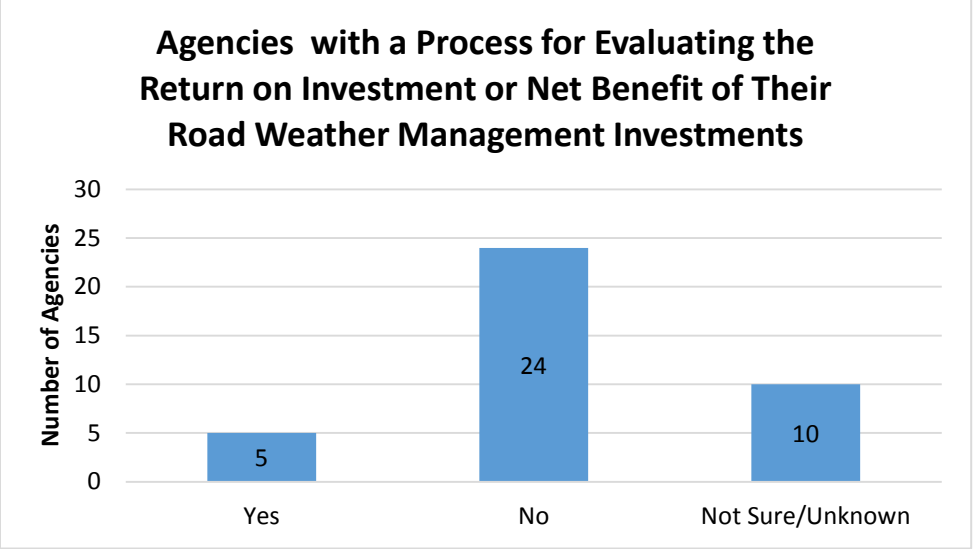

Figure 4. Graph. Number of Agencies that Evaluate Return-on-Investment or Net Benefits of Road Weather Management.

PM #5: Reductions in agency costs of winter 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, a data compilation created and maintained by the United States Department of Transportation (USDOT) Federal Highway Administration (FHWA) Office of Highway Policy Information (OHPI).[(11)] Figure 5 shows the national expenditures for snow and ice removal for a 12-year period between 2001 and 2012. The previous FHWA RWMP Performance Measurement Report tracked this data for the ten year period between 2001 and 2010.[(12)] The current report shows 12 years of data updated through 2012 with the last three years (2010, 2011, and 2012) highlighted.[(13)]

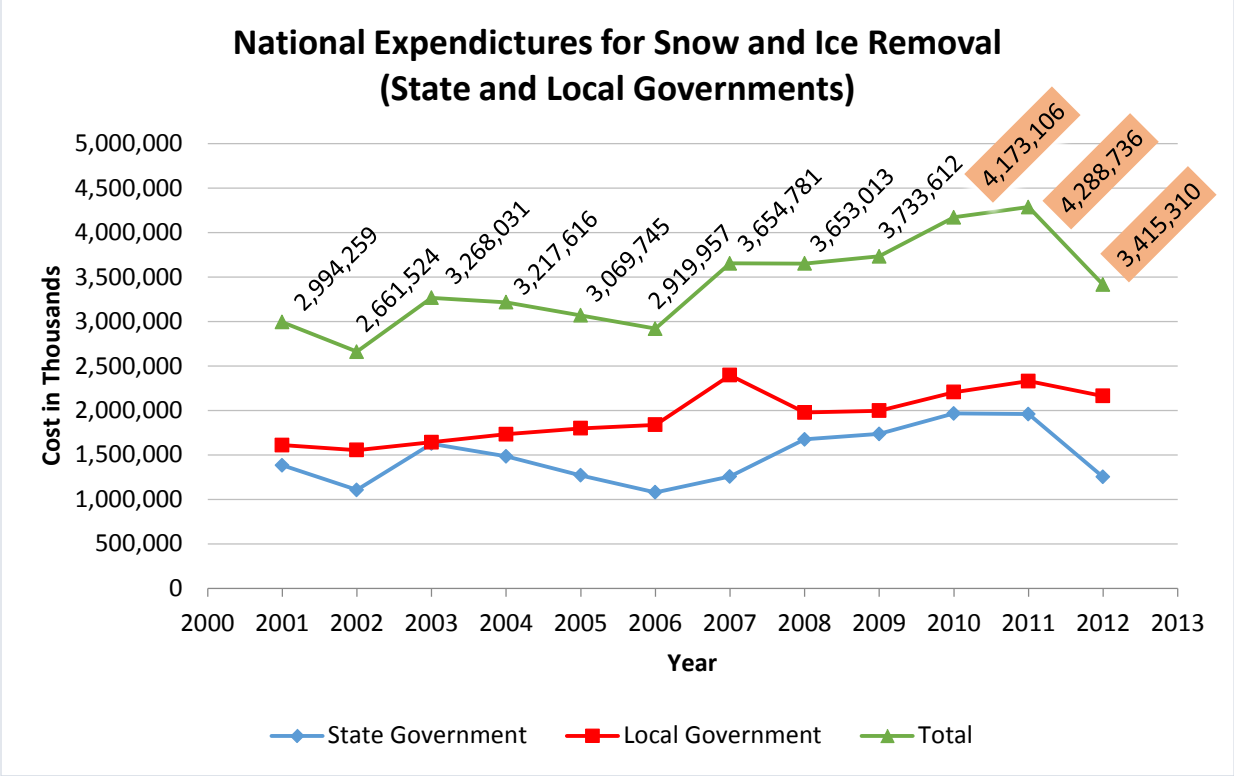

Figure 5. Graph. Annual Expenditures for Snow and Ice Removal (State and Local Governments).

[11] Data Source: Highway Statistics (2001 – 2012), Data Tables SF-4C (Disbursements for State-Administered Highways) and LGF-2 (Local Government Disbursements for Highways). Available at: http://www.fhwa.dot.gov/policyinformation/statistics.cfm.

[12] Federal Highway Administration, *Road Weather Management Performance Measures – 2012 Update*. FHWA-JPO-13-87, 2013. Available at http://ntl.bts.gov/lib/51000/51000/51065/26615E33.pdf.

[13] At the time of this report, 2012 data was the latest available data published in the Highway Statistics publication series.

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.

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. Most States in the Midwest and East Coast have reported historic spending on snow removal due to the increasing price of road salt and sand. For example, New Jersey, Illinois, and Georgia have spent over $97.7 million, $100 million, and $2 million, respectively, for snow and ice removal in the year 2014.(14) North Carolina's Department of Transportation (NCDOT) has also spent over 30.1 million going over the budgeted $30 million, $12.9 million of which was spent in a week alone.(15)

Planners have also had trouble allocating budget for road salt, maintenance, labor and equipment due to unpredictable weather patterns in recent years. Cities typically base budgets on reports from the past three to five years. Boston's funding for snow removal services has increased throughout the years with a winter budget of $18.5 million set aside for the year 2014.(16) Comparing that to funds in 2005, there has been an increase of $10.8 million in just 9 years.

Boston is not the only city surpassing the preset budget for snow removal. The St. Louis region has been experiencing severe winter seasons causing an increase in the budget for winter maintenance. The metropolitan area spent approximately $4.2 million just a month in through the winter of 2014.(17) The situation is similar in Illinois, where Illinois DOT was running approximately 70 to 80 percent ahead of a normal year during the winter season of 2014.(18)

The centerpiece of RWMP efforts to reduce agency costs for weather related maintenance and operation activities pertain to Maintenance Decision Support System (MDSS) development and adoption. MDSS is intended to provide agencies with more accurate and route-specific weather forecasts and road weather condition information by providing time and location specific weather forecasts along transportation routes. 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

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14 Michel, Erica. "Budget–Breaking Snow Year." *The National Congress of State Legislation Blog*, February 28, 2014. Accessed October 1, 2015. Available at: http://www.ncsl.org/blog/2014/02/28/budget-breaking-snow-year.aspx.

15 Marklein, Mary. "Relentless Winter Saps Snow-removal Budgets." *USA Today*, February 6, 2014. Accessed July 1, 2015. Available at: http://www.usatoday.com/story/news/nation/2014/02/06/snow-removal-budgets-tapping-out/5225805/.

16 Levenson, Eric. "Why Boston's Snow Removal Budget So Often Comes Up Short." *Boston.com*, November 13, 2014. Accessed June 24, 2015. Available at: http://www.boston.com/news/local/massachusetts/2014/11/13/why-boston-snow-removal-budget-often-comes-short/wSsqr91N08AugheqUxz7VM/story.html?p1=related_article_page.

17 "Missouri and Illinois Snow Removal Budgets Dwindling." *CBS St. Louis*, January 24, 2014. Accessed June 13, 2015. Available at: http://stlouis.cbslocal.com/2014/01/24/missouri-and-illinois-snow-removal-budgets-dwindling/.

18 "Missouri and Illinois Snow Removal Budgets Dwindling." *CBS St. Louis*, January 24, 2014. Accessed June 13, 2015. Available at: http://stlouis.cbslocal.com/2014/01/24/missouri-and-illinois-snow-removal-budgets-dwindling/.

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.

Since the publication of the 2012 report which documented the benefits of MDSS and other winter maintenance activities, limited evaluation reports have been published documenting savings. Some States have reported the findings of case studies that documented reductions in winter maintenance costs. The Michigan Department of Transportation (MDOT) provided benefit-cost calculations for two weather related deployments, Road Weather Information Systems (RWIS) and Maintenance Tracking using Global Position System (GPS). The potential benefits of these deployments are crash reduction during adverse weather and operating cost savings through more efficient use of winter maintenance resources. The results were positive, showing higher benefit-cost ratios in the Bay and the Grand regions with ratios of 7.0 and 5.1, respectively.(19)

The Idaho Transportation Department (ITD) has implemented a winter performance index that uses RWIS data in conjunction with maintenance response data to monitor snow and ice performance measurement. While the results cannot be solely attributed to the use of the winter performance index, ITD reported that a significant reducing trend in costs from the base year (2010/2011).(20)

The Utah Department of Transportation (UDOT) has implemented a proactive winter maintenance operations program to assist the agency with effective planning strategies that will allow area-specific weather forecasts. A case study was completed in order to quantify this value and compare it to the costs of obtaining such customized weather information. The results estimated the value and additional saving potential of the Utah DOT weather service to be 11 percent to 25 percent and 4 percent to 10 percent of the Utah DOT labor and materials cost for winter maintenance, respectively. On the basis of the program's cost, the benefit—cost ratio was calculated at over 11:1.(21)

PM #6: Reduction in number and types of fatalities and crashes attributed to adverse weather nationally

On average, there are over 5,870,000 vehicle crashes (resulting in injuries or fatalities) annually, twenty-three (23) percent of which are attributed to adverse weather and its effect on visibility and road surface conditions.(22) This measure tracks the reduction in nationwide numbers and types of fatalities attributed to adverse weather. Databases like the Fatality Analysis Report

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19 USDOT, Office of the Assistant Secretary for Research and Technology, ITS-JPO, "Knowledge Resources - Benefits Database: Rural Road Weather Information System deployments show estimated benefit-cost ratios of 2.8 to 7.0." Available at: http://www.itsbenefits.its.dot.gov/its/benecost.nsf/ID/E516FB20F38316728525788B0069DB05.

20 ITD, "Idaho Transportation Department Winter Performance Measures," Presentation at the Road Weather Capability Maturity Workshop Meeting by Robert Koeberlein, Operations Engineer, September 2015

21 Strong, Christopher, and Xianmind Shi. "Benefit-Cost Analysis of Weather Information for Winter Maintenance: A Case Study." *Transportation Research Record: Journal of the Transportation Research Board: Volume 2055*. Accessed June 20, 2015. Available at: http://trrjournalonline.trb.org/doi/pdf/10.3141/2055-14.

22 U.S. DOT FHWA Office of Operations Road Weather Management Program, "How do Weather Events Impact Roads?" Accessed October 1, 2015. Available at: http://www.ops.fhwa.dot.gov/weather/q1_roadimpact.htm.

System (FARS), National Highway Traffic Safety Administration's (NHTSA) National Automotive Sampling System (NASS) General Estimates System (GES), and NHTSA's National Motor Vehicle Crash Causation Survey (NMVCCS) provide national level summaries. Table 11 summarizes the number of nationwide fatal crashes occurring during inclement weather (rain, snow/sleet, and other). Although the national level data had been showing a decreasing trend of the number of fatal crashes occurring during inclement weather, 2013 shows a slight increase.

Table 11. All Fatal Crashes versus Fatal Crashes during Inclement Weather.

Year	Fatal Crashes	Fatal Crashes During Inclement Weather	% Fatal Crashes During Inclement Weather	Fatal Crash Rate (Per Licensed Driver)	Fatal Crash Rate During Inclement Weather (Per Thousand Licensed Drivers)	Fatal Crash Rate (Per Billion VMT)	Fatal Crash Rate During Inclement Weather (Per Billion VMT)
2001	37,862	4210	11%	0.198	0.022	13.543	1.506
2002	38,491	4351	11%	0.198	0.022	13.480	1.524
2003	38,477	4642	12%	0.196	0.024	13.313	1.606
2004	38,444	4761	12%	0.193	0.024	12.967	1.606
2005	39,252	4368	11%	0.196	0.022	13.130	1.461
2006	38,648	3807	10%	0.191	0.019	12.821	1.263
2007	37,435	3743	10%	0.182	0.018	12.350	1.235
2008	34,172	3796	11%	0.164	0.018	11.480	1.275
2009	30,862	3410	11%	0.147	0.016	10.438	1.153
2010	30,296	2948	10%	0.144	0.014	10.213	0.994
2011	29,867	2949	10%	0.141	0.014	10.138	1.001
2012	30,800	2849	9%	0.145	0.013	10.372	0.959
2013	30,057	3157	11%	0.142	0.015	10.058	1.056

VMT – vehicle miles traveled
Sources: Fatal Crash Data sourced from FARS "Fatal Crashes by Weather Condition: USA" (2001-2013), available at http://www-fars.nhtsa.dot.gov/Crashes/CrashesTime.aspx. Population and Vehicle Miles Traveled Information sourced from Highway Statistics Reports (2001 – 2013) Tables (DL-1C) "Licensed Drivers by Sex and Ratio Population" and (VM-202) "Annual Vehicle-Miles of Travel," available at: http://www.fhwa.dot.gov/policyinformation/statistics.cfm.

Figure 6 and Figure 7 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 decreased since 2001, however the last four reported years have leveled out. 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 with a slight increase of 0.002 per thousand licensed drivers and 0.097 per billion vehicle miles traveled (VMT) in the year 2013.

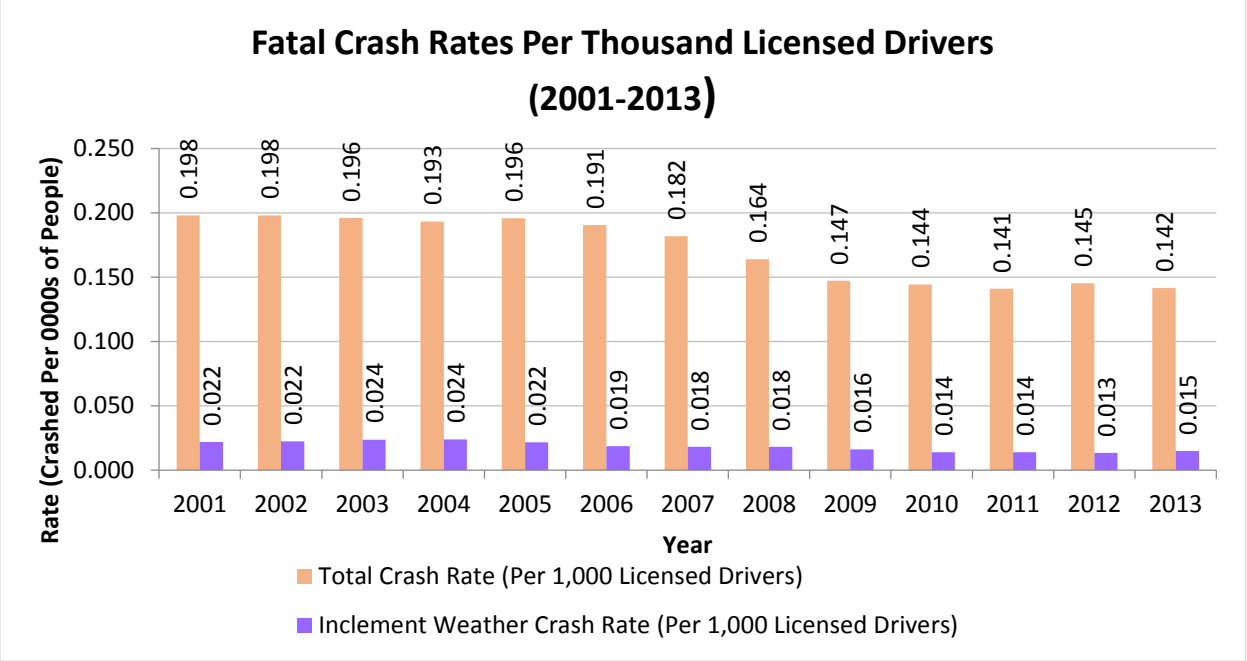

Figure 6. Graph. Fatal Crash Rates per 1,000 Licensed Drivers (2001-2013).

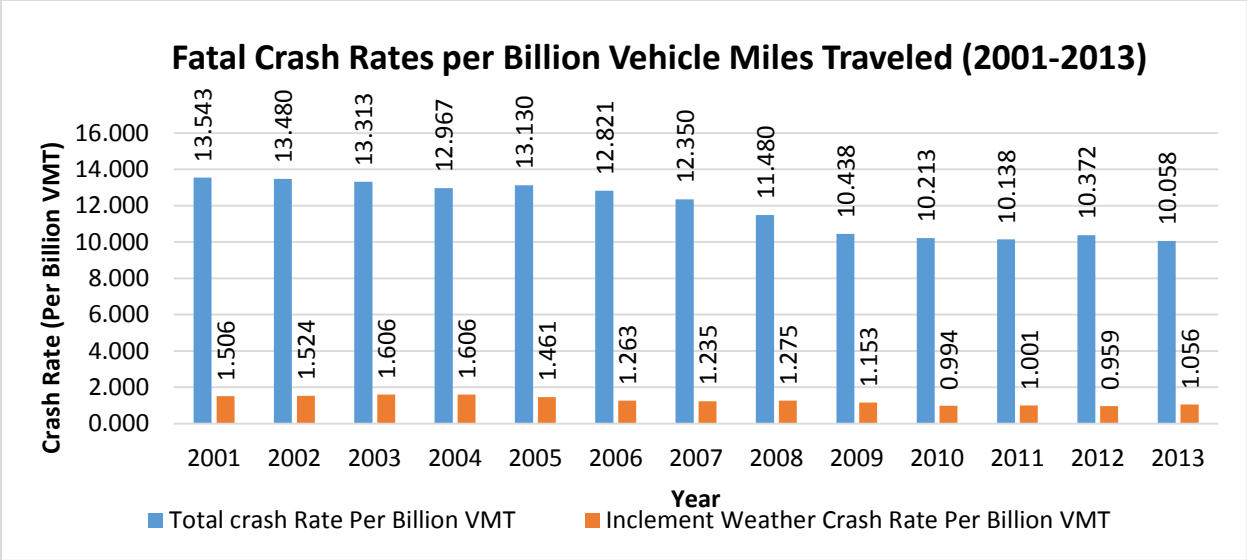

Figure 7. Graph. Fatal Crash Rates per Billion Vehicle Miles Traveled (2001-2013).

Table 12 further breaks down the weather-related crashes according to conditions. The majority of most weather-related crashes happen on wet pavement and during rainfall, 74 percent on wet pavement and 46 percent during rainfall. A much smaller percentage of weather related crashes occur during winter conditions.

Table 12. Weather-related Crash Statistics (Annual Average).

Road Weather Conditions	10-year Average (2002 – 2012)	10-year Percentages	
Wet Pavement	959,760 crashes	17% of vehicle crashes	74% of weather-related crashes
	384,032 persons injured	16% of crash injuries	80% of weather-related injuries
	4,789 persons killed	13% of crash fatalities	77% of weather-related fatalities
Rain	595,900 crashes	11% of vehicle crashes	46% of weather-related crashes
	245,446 persons injured	10% of crash injuries	52% of weather-related injuries
	2.876 persons killed	8% of crash fatalities	46% of weather-related fatalities
Snow/Sleet	211,188 crashes	4% of vehicle crashes	17% of weather-related crashes
	58,011 persons injured	3% of crash injuries	13% of weather-related injuries
	769 persons killed	2% of crash fatalities	13% of weather-related fatalities
Icy Pavement	154,580 crashes	3% of vehicle crashes	12% of weather-related crashes
	45,133 persons injured	2% of crash injuries	10% of weather-related injuries
	580 persons killed	2% of crash fatalities	10% of weather-related fatalities
Snow/ Slushy Pavement	175,233 crashes	3% of vehicle crashes	14% of weather-related crashes
	43,503 persons injured	2% of crash injuries	10% of weather-related injuries
	572 persons killed	2% of crash fatalities	10% of weather-related fatalities
Fog	31,385 crashes	1% of vehicle crashes	3% of weather-related crashes
	11,812 persons injured	1% of crash injuries	3% of weather-related injuries
	511 persons killed	2% of crash fatalities	9% of weather-related fatalities
Source: Federal Highway Administration Road Weather Management Program website			

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) Intelligent Transportation Systems (ITS) Benefits Database. The data in Table 13 are a compilation of the benefits reported in various deployments around the country since 2012.

Table 13. Examples of Road Weather Management Program Strategies Aimed at Reducing Crashes.

Strategy Used	Source	Reported Reduction in Crashes	State Reporting
ICWS	Best Practices for Road Weather Management, Version 3.0[(1)]	Reduced the number of annual crashes by 18%, and the system was estimated to provide safety benefits of $1.7 million per winter season.	California
Variable Speed Management System consisting of a complete RWIS	Best Practices for Road Weather Management, Version 3.0[(2)]	Winter maintenance resulted in zero winter weather related accidents (100% reduction) in one section of highway in Snowmass Canyon.	Colorado
VSL implementation	Variable Speed Limits System for Elk Mountain Corridor[(3)]	After the VSL implementation, crash rates reduced to the lowest level recorded in a decade. During this time, the total number of incidents and the number of injury crashes fell to 0.999 and 0.208 per MVMT in the year 2010, respectively. Recent updates in 2013 suggest further decrease in crash rates equating to about 50.1 crashes per year avoided.	Wyoming
FAST	Evaluation of North Dakota's Fixed Automated Spray Technology Systems[(4)]	Reports collected from January 1, 1996 through May 31, 2008 suggest that implementing the FAST system has reduced crashes 50-66% on bridge decks.	North Dakota
Automated Bridge Anti-Icing System	New Hampshire DOT Research Cord[(5)]	It is estimated that an early morning icing of the deck could expose drivers to hazardous conditions for as much as 90 minutes before conventional treatment could become effective. The pre-emptive treatment of this deck reduces the exposure to zero while it is in operation. It is clear that the safety level at this bridge is significantly elevated.	New Hampshire

Table 13. Examples of Road Weather Management Program Strategies Aimed at Reducing Crashes. (Continuation)

Strategy Used	Source	Reported Reduction in Crashes	State Reporting
Use of Winter Performance Measure Index	Idaho Transportation Department	Using three year blocks of time, ITD reported a 27% decrease in accidents since the deployment of the winter performance measures index program coupled with the use of RWIS technology.(6)	Idaho

DOT – department of transportation
FAST – fixed automated spray technologies
ICWS – ice curve warning system
ITD – Idaho Transportation Department
MVMT – million vehicle miles traveled
RWIS – road weather information systems
VSL – variable speed limits

[1] USDOT, Office of the Assistant Secretary for Research and Technology, ITS-JPO, "Knowledge Resources - Benefits Database - Benefit ID: 2013-00891." Available at: http://www.itsbenefits.its.dot.gov/its/benecost.nsf/ID/6A6939B150A9BA5485257C4A0058CDA7.
[2] USDOT, Office of the Assistant Secretary for Research and Technology, ITS-JPO, "Knowledge Resources - Benefits Database - Benefit ID: 2014-00894." Available at: http://www.itsbenefits.its.dot.gov/its/benecost.nsf/ID/AF7DACC99A687A9285257C58006EAFCC.
[3] USDOT, Office of the Assistant Secretary for Research and Technology, ITS-JPO, "Knowledge Resources - Benefits Database - Benefit ID: 2011-00733." Available at: http://www.itsbenefits.its.dot.gov/its/benecost.nsf/ID/86DB0BA6A9B08E03852578C000715F5F.
[4] USDOT, Office of the Assistant Secretary for Research and Technology, ITS-JPO, "Knowledge Resources - Benefits Database - Benefit ID: 2011-00733." Available at: http://www.itsbenefits.its.dot.gov/its/benecost.nsf/ID/86DB0BA6A9B08E03852578C000715F5F.
[5] New Hampshire Department of Transportation, "Evaluation of an Automated Bridge Anti-icing System," Report No. FHWA-NH-RD-13733G, January 2014. Available at: http://ntl.bts.gov/lib/52000/52500/52514/FHWA-NH-RD-13733G.pdf.
[6] ITD, Idaho Transportation Department Winter Performance Measures, Presentation at the Road Weather Capability Maturity Workshop Meeting by Robert Koeberlein, Operations Engineer, September 2015.

PM #7: Reduction in the extent of capacity losses and delays due to fog, snow, and ice events including freight

Roughly half of congestion experienced by travelers in the United States is caused by temporary disruptions or nonrecurring congestion. Inclement weather (snow, ice and fog) is one of the main causes of non-recurring congestion, attributing to 15 percent of this type of delay.(23) This is estimated to result in an annual delay of 544 million vehicle-hours of delay across the country.(24) In addition, snow accumulation, precipitation (type, rate, and start/end times), extreme wind speeds, and water levels also lead to a decrease in capacity.

[23] USDOT FHWA Office of Operations Road Weather Management Program, "Operations Story." Accessed October 1, 2015. Available at: http://ops.fhwa.dot.gov/aboutus/opstory.htm.
[24] USDOT FHWA Office of Operations Road Weather Management Program, "How do Weather Events Impact Roads?" Accessed October 1, 2015. Available at: http://ops.fhwa.dot.gov/weather/q1_roadimpact.htm.

Weather events can reduce arterial mobility and reduce the effectiveness of traffic signal timing plans. On signalized arterial routes, speed reductions can range from 10 to 25 percent on wet pavement and from 30 to 40 percent with snowy or slushy pavement. Furthermore, average arterial traffic volumes can decrease by 15 to 30 percent depending on road weather conditions and time of day. Travel time delay on arterials can increase by 11 to 50 percent and start-up delay can increase by 5 to 50 percent depending on severity of the weather event.[25] While information for freight delays due to weather events are not readily available, one study indicates that nearly 12 percent of total estimated truck delay is due to weather in 20 cities with the greatest volume of truck traffic. The estimated cost of weather-related delay to trucking companies ranges from $2.2 billion to $3.5 billion annually.[26] Another study found that weather phenomena impact freight traffic between 3 percent and 6 percent of the time, depending on location, with a national average of 4.6 percent. The cost of weather-related delay to the freight industry was estimated at $8.659 billion or 1.6 percent of the total estimated freight market of $574 billion.[27]

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.[28] The database reports RWMP best practices implemented by State DOTs resulting in reductions in capacity loss and delays associated with adverse weather. Limited evaluations have been found beyond those reported in 2012.

Table 14 below highlights impacts of two strategies on traffic flow implemented in Utah, Idaho and Oregon.

Table 14. Traffic Flow Impacts Due to Road Weather Management Program Identified Best Practice Technologies and Techniques.

Strategies	Traffic Flow Impacts	Reporting State
Use of Winter Performance Measure Index	ITD measures the percent of Time Highways Clear of Snow/Ice During Winter Storms with a target to maintain at least 60% unimpeded mobility during winter storms. ITD has been able to increase this percent from 28% to 77% over a period of 5 years.(1)	Idaho
Weather Responsive Signal Control System	During severe winter weather events, travel times were improved by 3 percent and reduced overall stopped times by 14.5 percent.(2)	Utah

[25] USDOT FHWA Office of Operations Road Weather Management Program, "How do Weather Events Impact Roads?" Accessed October 1, 2015. Available at: http://ops.fhwa.dot.gov/weather/q1_roadimpact.htm.
[26] USDOT FHWA Office of Operations Road Weather Management Program, "How do Weather Events Impact Roads?" Accessed October 1, 2015. Available at: http://ops.fhwa.dot.gov/weather/q1_roadimpact.htm.
[27] USDOT ITS Joint Program Office – HOIT, "Weather Delay Costs to Trucking," Report No. FHWA-JPO-13-023, November 2012. Available at: http://www.its.dot.gov/road_weather/pdf/weather_delays_trucking.pdf.
[28] USDOT, Office of the Assistant Secretary for Research and Technology, ITS-JPO, "Knowledge Resources - Benefits Database." Available at: http://www.itsbenefits.its.dot.gov/.

Table 14. Traffic Flow Impacts Due to Road Weather Management Program Identified Best Practice Technologies and Techniques. (Continuation)

Strategies	Traffic Flow Impacts	Reporting State
Mobile Traffic Application and Road Weather Reporting System	Respondents surveyed after two winter storms reported 83 and 95 percent satisfaction respectively per storm with UDOT's mobile traffic app and road weather reporting system. Drivers appreciate real-time, accurate weather information. The Citizen Assisted Reporter Program is seen as a good way to increase the availability and accuracy of weather and traffic information.(3) Citizen Reports supplement maintenance and meteorologist reports allowing for timelier, more accurate road condition information, which can improve decision-making for snow and ice removal activities. Mobile applications provide drivers with information to better plan their trips, potentially improving traffic flow.	Utah
Oregon OR-217 Weather Responsive ATM	During the first seven months of variable speed limits use in OR-217. Prior to VSL operations, peak hour travel times during wet conditions were three or four minutes greater than dry conditions. Post-VSL this dropped to 2.5 minutes. While it is difficult to completely attribute this to VSL since intensity and amount of precipitation play a role, some positive benefits have been attributed to the use of VSL in minimizing the degradation in performance.(4)	Oregon

ATM – active traffic management
ITD – Idaho Transportation Department
UDOT – Utah Department of Transportation
VSL – variable speed limits

[1] ITD, "Idaho Transportation Department Winter Performance Measures," Presentation at the Road Weather Capability Maturity Workshop Meeting by Robert Koeberlein, Operations Engineer, September 2015.
[2] USDOT, Office of the Assistant Secretary for Research and Technology, ITS-JPO, "Knowledge Resources - Benefits Database - Benefit ID: 2014-00927." Available at: http://www.itsbenefits.its.dot.gov/its/benecost.nsf/ID/1856A715BA3E6F9685257CF9006724D0.
[3] USDOT, Office of the Assistant Secretary for Research and Technology, ITS-JPO, "Knowledge Resources - Benefits Database - Benefit ID: 2014-00928." Available at: http://www.itsbenefits.its.dot.gov/its/benecost.nsf/ID/5E2910DFA5CF9E7285257D02006178E4
[4] Downey, M.B., *Evaluating the Effects of a Congestion and Weather Responsive Advisory Variable Speed Limit System in Portland, Oregon*, Portland State University, September 2015.

PM #8: 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.

The degradation of reliability can be associated with the seven causes of non-recurring congestion including: incidents, weather, work zones, fluctuation in demand, special events, traffic control devices and inadequate base capacity.

While each of these can occur independently and cause variations in normal travel times, they are not mutually exclusive. The causes of non-recurring congestion can have compounding effects. For example, weather 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 instance, 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.

Isolating the impacts of weather on travel time reliability is important for RWMP performance evaluation. However, there are 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 reporting that on average, adverse weather results in twice the travel time variability compared with that under normal weather conditions. [(29)] 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. The Strategic Highway Research Program 2 (SHRP2) performance measure 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 environmental sensor stations (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 recurrent condition.

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.[(30)] However, the information available is not at a level that can be used for assessing the performance of the RWMP products, activities and services.

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

[30] USDOT FHWA Office of Operations, Operations Performance Measurement Program, "Urban Congestion Reports." Available at: http://ops.fhwa.dot.gov/perf_measurement/ucr/.

One study in Oregon (Evaluation of the OR-217 ATM) discussed the impact of adverse weather on travel time noting that pre-variable speed limits (VSL), peak hour travel times during wet conditions were between 19 to 78%. After the VSL became active, the variation almost disappeared indicating that drivers were behaving more homogenously during adverse weather.[31]

PM #9: Reduction in the number of tons of salt or chemical usage in the United states 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 United States Geological Survey 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.

The USGS Minerals Yearbook reports that United States (U.S.) consumption of salt for ice control and road stabilization in 2013 was 20.4 million tons, which was 84 percent more than in 2012.[32]

Table 15 provides annual salt usage during inclement weather for ice control and road stabilization from 2006 through 2013.

Table 15. National Salt Consumption from Road Deicing.

Year	Percentage of Total Salt Use	Total Tons Used Road Deicing (millions)	% Change in Consumption from Previous Year
2006	29%	12.4	--
2007	39%	20.8	68%
2008	43%	22.6	9%
2009	38%	16.9	-25%
2010	38%	18.7	11%
2011	41%	19.6	5%
2012	30%	11.1	-43%
2013	43%	20.4	84%

Source: United States Geological Survey Minerals Yearbook: Salt (2006-2013)

The quantity of salt used for road deicing each year is directly related to the severity of winter weather conditions. Accurate forecasting of salt consumption is extremely difficult because of

[31] Downey, M.B., *Evaluating the Effects of a Congestion and Weather Responsive Advisory Variable Speed Limit System in Portland, Oregon,* Portland State University, September 2015.

[32] Bolen, William. *2013 Minerals Yearbook.* Available at: http://minerals.usgs.gov/minerals/pubs/commodity/salt/myb1-2013-salt.pdf .

the complexities in long‑range weather forecasting. One strategy for monitoring salt consumption used by Iowa DOT is a management dashboard featuring actual salt usage during maintenance operations compared to estimated usage amounts, based on road weather conditions. Managers monitor this dashboard to make sure current usage is reasonable given the weather and is within Iowa DOT's standard application rate guidelines.

Variability in winter weather severity and levels of service – from year to year and from place to place – makes performance measurement difficult. The use of a Winter Severity Index (WSI) has gained recognition as a way to gauge the relative severity of winter weather across various time frames or geographic regions.

Massachusetts DOT utilizes a WSI to compare annual road salt usage to the severity of the winter conditions that occur each season. Factors that are included with their WSI include: daily minimum and maximum temperatures, daily snowfall and the number of snowfall events each month. WSI and salt usage are positively correlated. In two recent years, the agency has seen more efficient use of salt (i.e., actual salt consumption was less than the amount estimated from the WSI-salt usage relationship).[33,34]

As information from Massachusetts DOT shows, 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. However, WSI factors vary from State to State as shown in Table 16. This variation makes it very difficult to evaluate salt usage since a direct comparison cannot be made.

[33] Massachusetts DOT, "MassDOT Snow & Ice Control Program – 2012 Environmental Status and Planning Report EOEA#11202 – Public Review Draft," February 2012. Available at: http://www.massdot.state.ma.us/Portals/8/docs/environmental/EnvironStatus_PlanningRpt_0212.pdf .

[34] Massachusetts DOT, "The GreenDOT Report - 2014 Status Update," December 2014. Available at: http://www.massdot.state.ma.us/Portals/0/docs/GreenDOT/GreenDOT_Report2014/statusReport_GreenDOT2014.pdf

Table 16. Examples of State Winter Severity Indices.

State	Winter Severity Index (WSI) Factors	WSI Description
Washington[1]	FI 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[2]	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). Average statewide WSI for 2011-12 Winter was 24.33 and for 2012-13 Winter, 37.17. The 2012-2013 winter season was much more severe than the mild winter of 2011-2012. Snowfall was much heavier statewide, with an average of approximately 93 inches. This was approximately double the snowfall total of the previous winter.
Idaho[3]	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.
Minnesota[4]	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[5]	Daily minimum temperatures. Daily maximum temperatures. Daily snowfall. Number of snowfall events per month.	MassDOT uses a WSI to compare annual road salt usage to the severity of the winter conditions that occur each season. WSI values generally range from 0 to 50, with 50 representing the most severe conditions.
New Hampshire[6]	High/low temperatures. Snowfall amount. Computed on a monthly basis for the months of November, December, January, February and March.	The New Hampshire Department of Transportation has used a WSI that was developed by Washington State University and published in the report NCHRP H-350. A usage of 111,806 tons of salt for FY 2012 was predicted. The actual usage for FY 2012 was 112,660 tons, (an excess from predicted of 854 tons (0.76%). Given the sensitivity of the formula, this usage is statistically on target for the predicted versus actual usage.

Table 16. Examples of State Winter Severity Indices. (Continuation)

State	Winter Severity Index (WSI) Factors	WSI Description
Maine[7]	Historical snowfall data, daily snowfall amounts, ambient temperature, and liquid precipitation	Maine views the WSI as a helpful tool to help evaluate the effectiveness of winter maintenance equipment, crews, and methods of fighting snow.

FI – frost index
NCHRP – National Cooperative Highway Research Program
WSI – winter severity index

[1] Transportation Research Board of the National Academies, *Transportation Research Circular (Number E-C063): Sixth International Symposium on Snow Removal and Ice Control Technology*, June 2004. Available at: http://onlinepubs.trb.org/onlinepubs/circulars/ec063.pdf.

[2] Wisconsin DOT, *2012-2013 Annual Report*.

[3] Transportation Research Board of the National Academies, *Transportation Research Circular (Number E-C063): Sixth International Symposium on Snow Removal and Ice Control Technology*, June 2004. Available at: http://onlinepubs.trb.org/onlinepubs/circulars/ec063.pdf.

[4] Minnesota DOT, *2010–2011 Annual Winter Maintenance Report at a Glance*. Available at: http://www.dot.state.mn.us/maintenance/pdf/research/winterataglance.pdf.

[5] Massachusetts DOT, "MassDOT Snow & Ice Control Program – 2012 Environmental Status and Planning Report EOEA#11202 – Public Review Draft," February 2012. Available at: http://www.massdot.state.ma.us/Portals/8/docs/environmental/EnvironStatus_PlanningRpt_0212.pdf.

[6] New Hampshire DOT, "Effective Resource Management – 2012." Available at: http://www.nh.gov/dot/org/commissioner/balanced-scorecard/department/documents/2012_bs_performance_salt_usage.pdf.

[7] Maine DOT Transportation Research Division, *A Winter Severity Index for the State of Maine*, Technical Report 09-1, January 2009. Available at: http://ntl.bts.gov/lib/54000/54500/54542/report0901f.pdf.

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 technologies (i.e., deicing and anti-icing methods), agencies can optimize their usage of materials, thereby providing safe mobility while reducing the amount of salt on the highways. However, no new studies were found in the 2012-2015 relating to documented benefits in salt usage.

Summary

Overall, the importance of performance measurement and return on investment continues to grow. However, there are limited examples of evaluation studies since the 2012 update. In itself, it is not surprising since evaluation studies require several winters' worth of data to be meaningful. However, the paucity of evaluation studies leads to reduced acceptance and adoption of some of the road weather management strategies. At a programmatic level, the lack of consistently defined measures continues to be a challenge.

CHAPTER 6. OBJECTIVE 3: TRANSPORTATION, WEATHER, AND RESEARCH COMMUNITIES USE AND RELY UPON FIXED AND MOBILE ROAD WEATHER OBSERVATIONS

The transition from *Clarus* to the Meteorological Assimilation Data Ingest System (MADIS) signals momentum towards the creation of a national operational system of real-time (or near real-time) and archived observational road weather data. Ultimately, MADIS will offer a robust set of quality data that will be available to support traffic management, inform maintenance decision-making and performance measurement, and provide information on current conditions to the traveling public. The performance measures (PM) under Objective 3 capture progress towards continued growth in the use of fixed and mobile road weather observations by State departments of transportation (DOT). Additionally, this objective not only examines the availability of data, but also the subscription rates and use of observational data at State DOTs – which gauge the impact of the availability of data on strategic and tactical decision-making for weather-related maintenance and traffic operations.

PM #10: Number of State departments of transportation that are participants in the Meteorological Assimilation Data Ingest System program

The transition from *Clarus* to MADIS is a new activity since the 2012 update. The Road Weather Management Program (RWMP) is supporting the National Oceanic and Atmospheric Administration (NOAA) by working with State DOTs to secure data sharing agreements and helping to ensure data quality by integrating quality checking algorithms into the system. This performance measure tracks the number of State DOTs that are participating in the MADIS program by signing a data sharing agreement and providing real-time data to MADIS. According to RWMP records, twelve States have participated in the MADIS program as of April 2015, as shown below in Figure 8. These states are: Alaska, Arizona, Iowa, Idaho, Kentucky, Minnesota, Missouri, Montana, North Dakota, New York, Oregon, and Vermont.

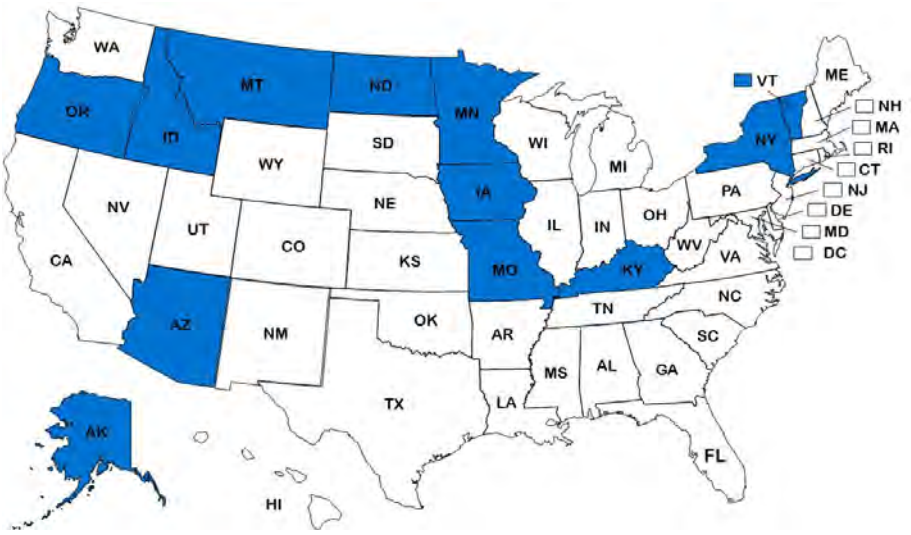

Figure 8. Chart. State Departments of Transportation Participating in the Meteorological Assimilation Data Ingest System Program.

PM #11: Number of State Departments of Transportation that subscribe to road weather products and services

This performance 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. In addition to mass media, various weather data are available to agencies from both public and private sources including information from the NWS, the Federal Aviation Administration (FAA), sensors deployed by federal and State agencies, and private-sector value-added services. In recent years, social media outlets have become a source of information as well. The RWMP has played a vital role in the development, promotion, and distribution of road weather information. Coordination with the National Weather Service (NWS) and Office of the Federal Coordinator for Meteorological Services (OFCM) has helped bring the needs of 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 encourages 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. 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.

This measure compares the percentage of States subscribing to road weather products and services in 2007, 2013, and 2015. Data from 2007 were obtained from the Intelligent Transportation Systems (ITS) Deployment Statistics survey; 2013 and 2015 data are from the respective RWMP surveys of State DOTs. Figure 9 shows the percentage of State DOTs that used selected sources of road weather information. However, because these data are derived from two different types of surveys with different wording and sets of respondents, they are not fully comparable. However, the results show that subscription to National Weather Service Products held steady since 2013. There has been a slight increase in the use of agency sensors (road weather information systems [RWIS]/probes), and a slight decrease in use of Private Weather Service Providers, agency field personnel, and Federal Aviation Administration (FAA) (automated surface observing system [ASOS], automated weather observing system [AWOS]) products. There was a precipitous decline in the use of National Sensor Data sources (i.e., MADIS or previously *Clarus*). This is likely attributed to the recent transition from *Clarus* to MADIS and is likely a temporary blip as full transition between MADIS and *Clarus* occurs.

The respondents identified other sources of weather and road weather information, including: maintenance decision support systems (MDSS), mobile weather sensors (air temp, road temp, relative humidity, dew point, etc.); internet websites and applications; and University Meteorology Departments.

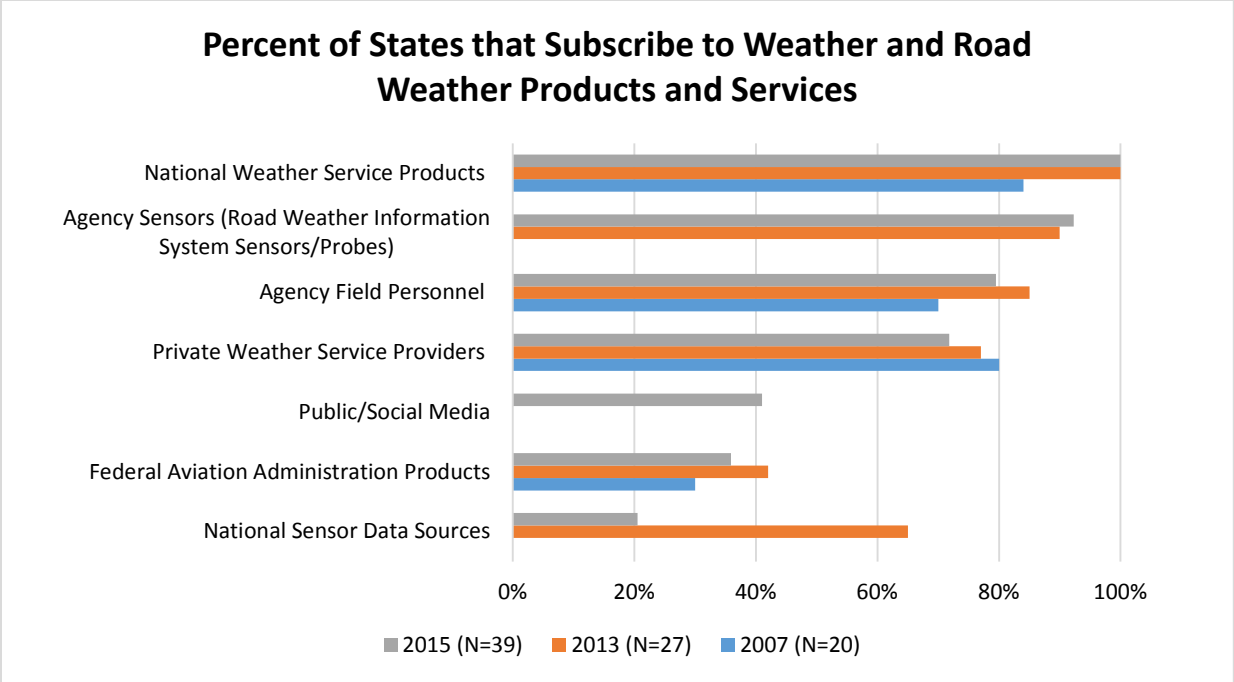

Figure 9. Graph. Percent of States that Subscribe to Weather and Road Weather Products and Services.

PM #12: Number of State Departments of Transportation collecting mobile observations of road weather data from appropriate vehicle fleets

This measure tracks the growth in the collection and use of mobile observations of road weather data from vehicle fleets. In addition to vehicle location data from Automatic Vehicle Location (AVL) systems and radio communication between the driver and the maintenance center, mobile road weather observations can also include 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 promising 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. Major activities/projects of interest for the performance measures update include:

- **Integrated Mobile Observations (IMO)** – This program seeks to collect data from maintenance fleets that are equipped with AVL/MDSS technologies 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 Nevada, Minnesota and Michigan DOTs, 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 weather information.
- **Dynamic Mobility Applications (DMA)** – 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.

Increased use of mobile observations will support a wide variety of strategic and tactical decision-making for State DOT maintenance and traffic operations. In the State DOT survey, respondents were asked whether their agencies collect real-time field data from maintenance vehicles and from what percentage of the applicable fleets. This year, the survey also included a question to identify the type of data that are collected from maintenance vehicles, as well as from what percentage of the applicable fleets (Figure 10).

Overall, 50 percent of States surveyed collect real-time field data from maintenance vehicles. Figure 10 shows the type of data collected and from what percentage of the applicable vehicle fleets. The results of the survey show that collecting data fleet-wide is starting to become a practice; as many as three DOTs reported using 100 percent of the fleet to collect data, compared to zero in 2013.

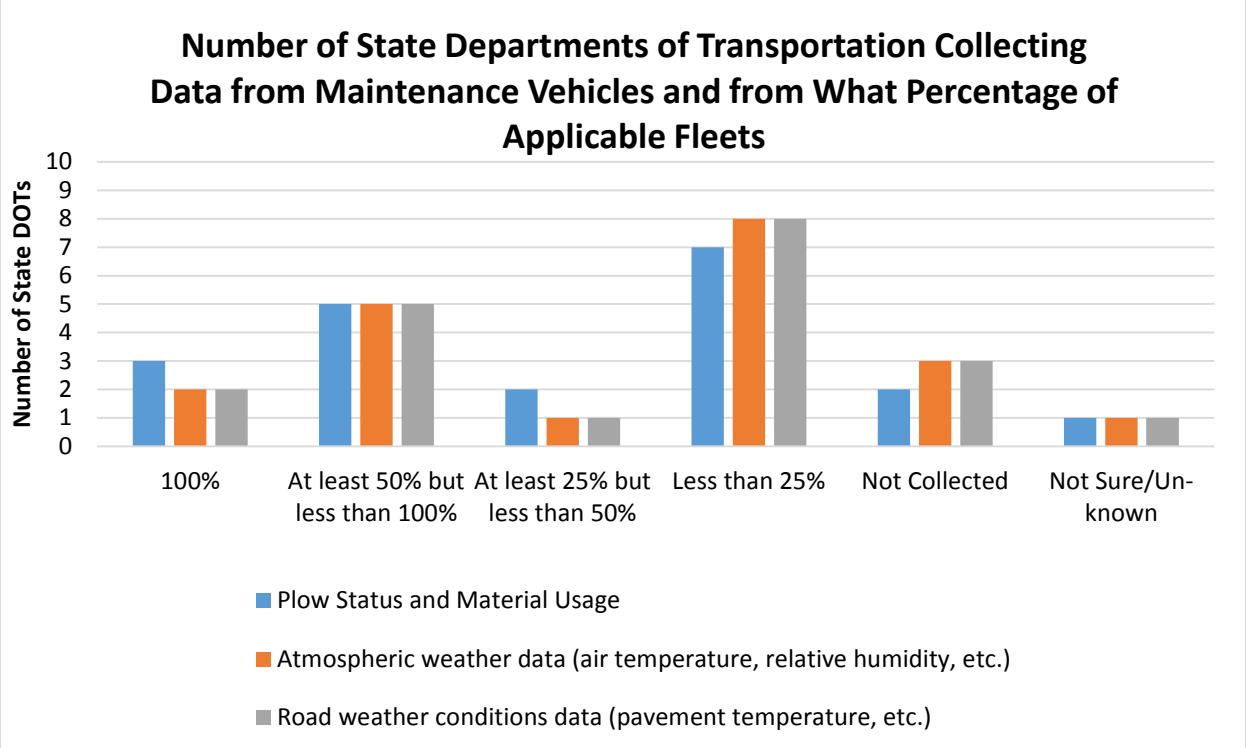

Figure 10. Graph. Number of State Departments of Transportation Collecting Data from Maintenance Vehicles and From What Percentage of Applicable Fleets.

PM #13: Number of State Departments of Transportation reporting the use of Environmental Sensor Stations in operations and maintenance activities

This performance measure tracks the number of fixed ESS that exist in the United States and how they are used in operations and maintenance activities. This definition is slightly different from previous updates where this measure tracked only the number of ESS sensors.

While the number of ESS deployed is an important statistic, it can be misleading. First, since many States have already deployed ESS, the number in those States is not expected to increase substantially in the coming years. Second, not all installations of ESS may be used in support of operations and maintenance activities.

In the State DOT survey, the respondents reported a total of 2,473 ESS. This is a slight decrease from 2,499 in the 2012 report. Figure 11 depicts how ESS are used to support road weather management. The most common use of ESS is to support traffic management and maintenance decision-making; more than 90 percent of responders report this use. The majority of agencies also use ESS data to provide current conditions to traveler information systems (61 percent) and input for segment-level forecasts (58 percent).

Respondents also identified other uses for ESS including: after-action reports and performance assessment post weather events, providing the data to the public through the agency website, and uploading it to the State's 511 system to make it easier for freight, transit, and the traveling public to access this information in order to make more informed decisions.

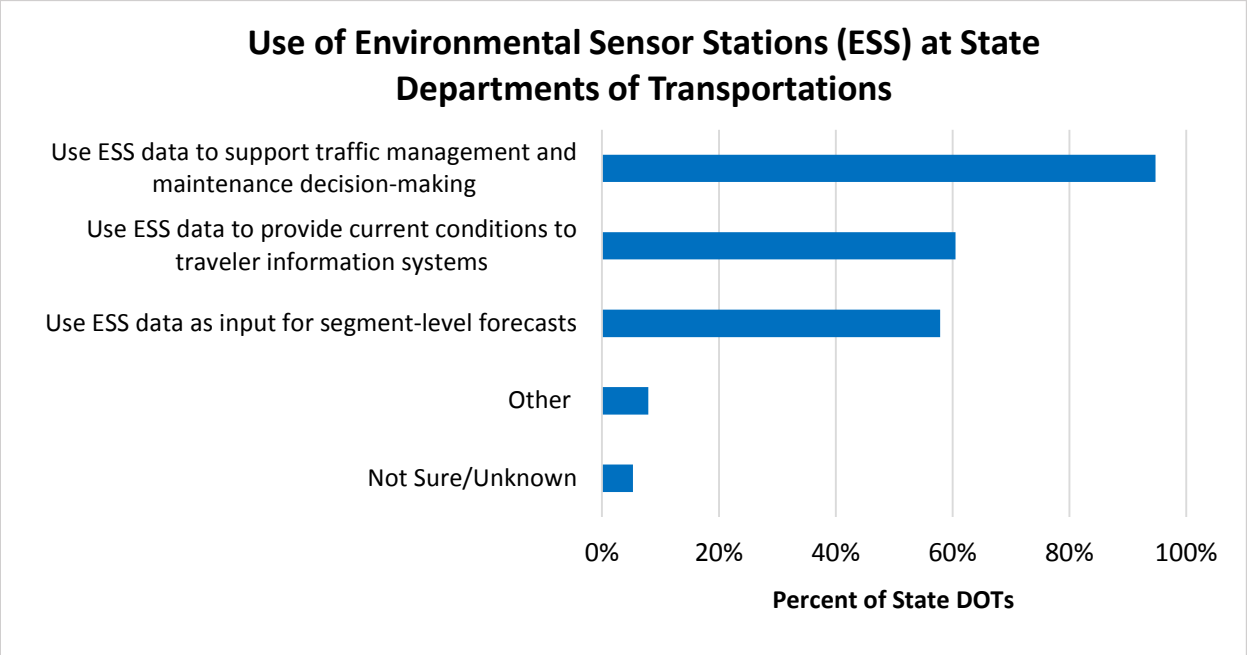

Figure 11. Graph. Use of Environmental Sensor Stations at State Departments of Transportation.

Summary

The performance measures demonstrate overall success for the activities under Objective #3, indicating progress in these early stages of the development and application of a national database of observational data (i.e., MADIS). As of early 2015, twelve State DOTs have data sharing agreements. These early implementers are comprised primarily of States with higher levels of engagement in RWMP activities. In the future, a concerted effort may be needed to help NOAA establish data sharing agreements with those States with lower levels of engagement to meet the goal of the MADIS program.

Additionally, the results show modest strides in the collection of mobile observations of road weather data from vehicle fleets, specifically the collection of data using the entire DOT fleet is beginning to emerge as a practice. However, there is still room for significant improvement, as the largest group of respondents reported collecting mobile data from less than 25 percent of the fleet. There was a slight decrease in the number of reported ESS, but this is not very surprising as the 2012 Update noted that a major increase in the overall number of stations was not expected (given the nature of ESS deployment). The results also indicate widespread application of data to support traffic management and maintenance decision-making. Ninety-five percent of State DOTs reported using ESS data for decision-making.

CHAPTER 7. OBJECTIVE 4: ADVANCE THE STATE OF THE ART FOR MOBILE SENSING AND INTEGRATING VEHICLE DATA INTO ROAD WEATHER APPLICATIONS

Translating mobile and fixed observations to meaningful applications to solve problems for road weather management is the goal for this objective. Building from the growing number of States collecting mobile data, activities under this objective are geared towards showcasing applications that demonstrate the added value of mobile sensing in road weather management. The following performance measure (PM) tracks progress for this objective.

PM #14: Number of/percentage of responding agencies using mobile data-based applications in road weather management

As part of the Connected Vehicle Research track, the Federal Highway Administration (FHWA) Road Weather Management Program (RWMP) has been supporting the development of Vehicle to Infrastructure (V2I) applications that leverage mobile data and vehicle to infrastructure connectivity to support road weather management. This measure will begin tracking the number of agencies engaged in these activities. In the State departments of transportation (DOT) Survey, respondents reported on whether their agencies have developed applications or tools that rely on availability of real-time mobile data from vehicle fleets and/or vehicle-to-infrastructure connectivity. Figure 12 shows the extent to which State DOTs are developing applications or tools utilizing the availability of real-time data.

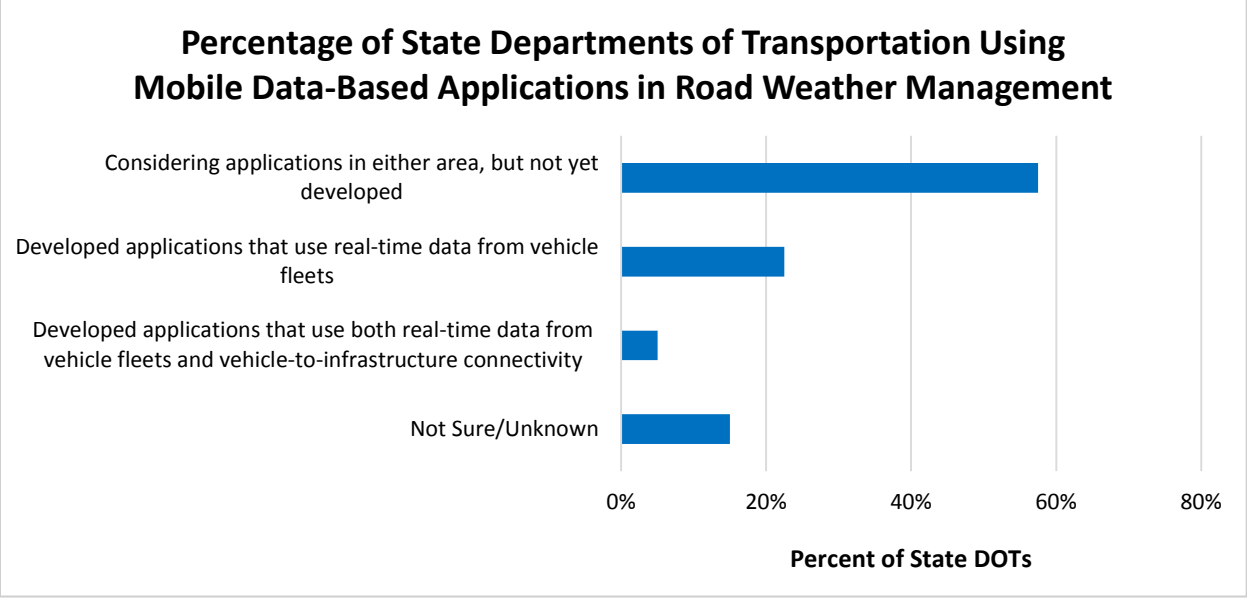

Figure 12. Graph. Percentage of State Departments of Transportation Using Mobile Data-Based Applications in Road Weather Management.

Summary

The results show that some State DOTs (23 percent) have developed applications that input real-time data from vehicle fleets, but fewer (5 percent) have developed applications that utilize data derived from vehicle fleets and vehicle-to-infrastructure connectivity. However, there is much potential for growth as expressed by significant interest from States that are considering the use of cutting-edge technologies to develop applications (58 percent).

CHAPTER 8. OBJECTIVE 5: ADVANCE THE STATE OF THE PRACTICE BY PROMOTING TAILORED MANAGEMENT STRATEGIES FOR DIFFERENT REGIONS

There is not a universal approach to developing and implementing strategies to address winter weather. On the contrary, there are a wide range of potential methods and strategies that can be tailored to address the unique local conditions (pavement conditions, etc.). The Road Weather Management Program (RWMP) encourages State departments of transportation (DOT) to create a customized approach to road weather management that accounts for the local context (e.g., road conditions, forecasts, etc.). The activities under Objective 5 assess the variability of management strategies and methods used by State DOTs in order to consider local conditions. Four performance measures (PM) are used to document progress for this objective.

PM #15: Number of States disseminating weather advisory and other road weather information to travelers

This measure focuses on State DOTs providing road weather advisory information to travelers. Advisory information may include pre-trip and en route cautionary messages, weather advisories, travel times, accident reports, pavement surface conditions, and routing or diversion information. Types of weather information commonly disseminated to travelers include:

- Atmospheric observations (e.g., precipitation and air temperature from environmental sensor station (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).
- Weather advisories (e.g., National Weather Service [NWS] watches and warnings).
- Weather forecast data (e.g., weather service provider-generated weather forecasts).
- Route-specific road weather forecasts.

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 13 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 2004 and 2007 data is the Intelligent Transportation Systems (ITS) Deployment Statistics Survey. The 2015 data were pulled from the State DOT survey. For this update, the website, 511 phone systems and social media are merged into one category.

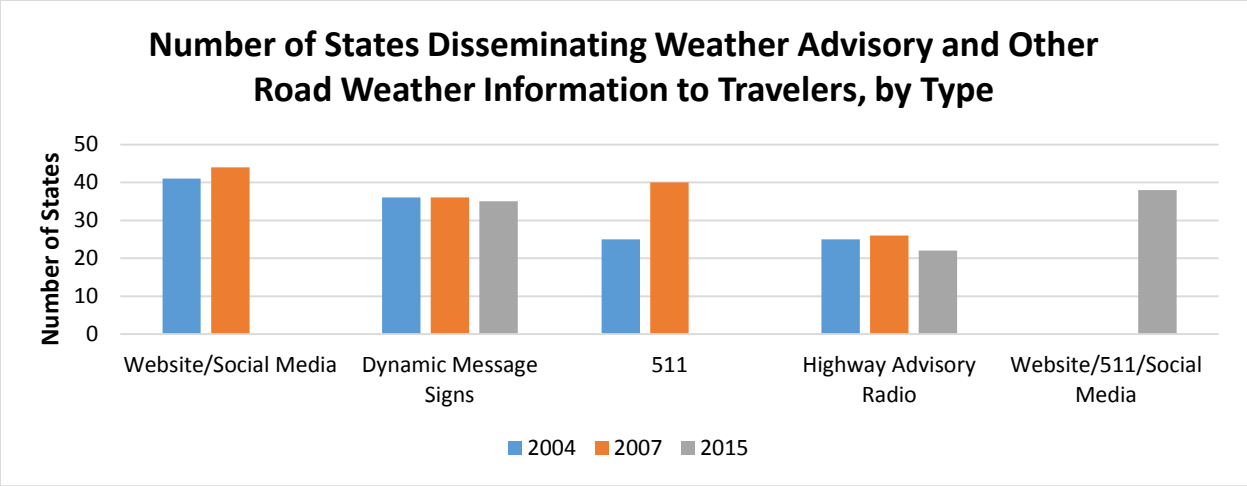

Figure 13. Graph. Number of States Disseminating Weather Advisory and Other Road Weather Information to Travelers, By Type.

As shown in Figure 14, online sources (website and social media) and 511 phone systems continue to be the most commonly used platforms to disseminate weather advisory and other information to the public. Use of HAR has decreased, and the use of dynamic messaging signs has decreased slightly.

In the 2015 State DOT survey, respondents also indicated the level of deployment for each type of communication platform.

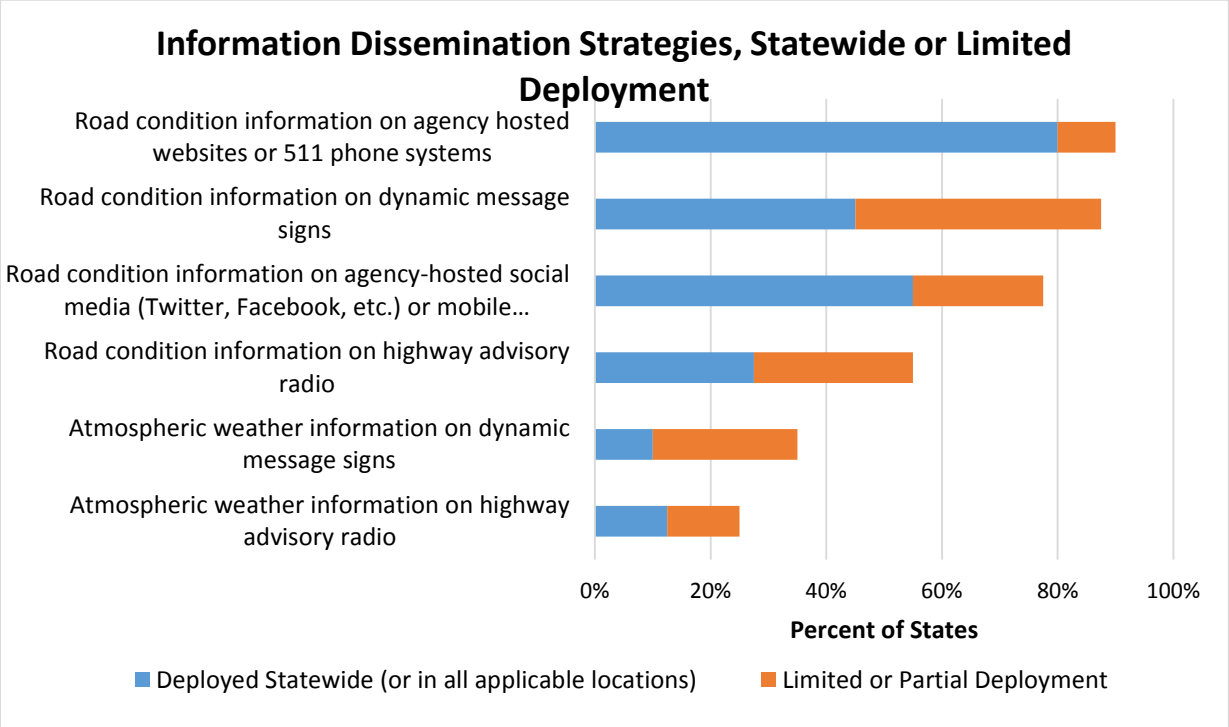

Figure 14. Graph. Information Dissemination Strategies.

Overall, providing road condition information on websites or 511 phone systems and DMS is more prevalent, followed by agency hosted social media and other mobile applications, and highway advisory radio. For atmospheric weather information, 35 percent of States reported full or partial deployment, and 25 percent reported full or partial use of highway advisory radio for disseminations.

The 2013 ITS Deployment Survey asked respondents whether they deployed safety warning systems related to road weather events. Seventeen (17) State DOTs responded that they do deploy safety warnings. Respondents also indicated for which types of hazards they have safety warning systems, shown in Figure 15.

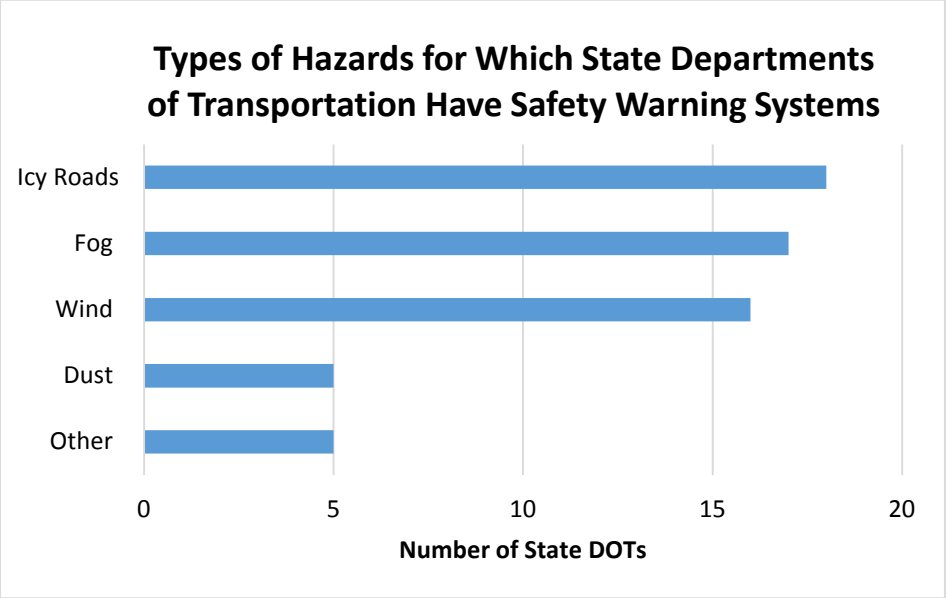

Figure 15. Graph. Types of Hazards for Which State Departments of Transportation Have Safety Warning Systems.

Safety warning systems are most commonly used for icy roads, followed by fog, wind, dust and other (not specified).

PM #16: Number of agencies using control and treatment strategies during weather events

Control and treatment strategies, like advisory strategies, are important and effective actions agencies can take in response to all types of road weather conditions. Control and treatment strategies include ramp meters, traffic signal timing, variable speed limits, etc. This performance measure assesses the type of strategies used in response to weather events and the extent to which they are deployed by State DOTs. Respondents to the State survey provided information on which strategies are used and whether they have statewide or limited/partial deployment. The results are shown below in Figure 16.

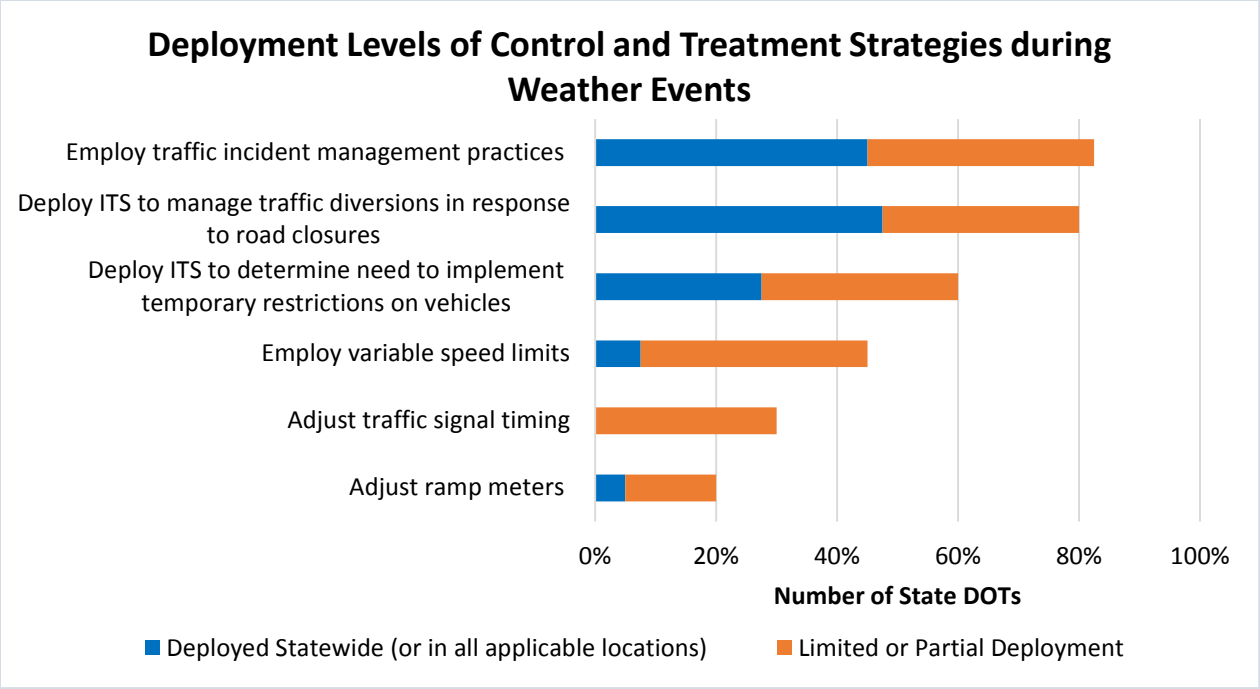

Figure 16. Graph. Level of Deployment of Control and Treatment Strategies during Weather Events.

The most widely deployed strategy, either partially or statewide, is employing traffic incident management practices (83 percent). The least commonly used strategy is ramp meter adjustment (20 percent). As shown in Table 17, the overall prevalence of control and treatment strategies remained largely the same, with the exception of ramp metering and traffic signal timing which changed places at the bottom of list.

Table 17. Rankings of Selected Control and Treatment Strategies (2013 and 2015).

Control and Treatment Strategy	2013 Ranking	2015 Ranking
Employ traffic incident management practices	1	1
Deploy ITS to manage traffic diversions in response to road closures)	2	2
Deploy ITS to determine need to implement temporary restrictions on vehicles	3	3
Employ variable speed limits	4	4
Adjust traffic signal timing	6	5
Adjust ramp meters	5	6

ITS – intelligent transportation systems

PM #17: Number of agencies that have participated in or conducted road weather management capability maturity assessment exercises

This measure assesses the number of agencies that have conducted or participated in capability maturity assessment exercises, in which agencies examine current practices and identify business

process improvements to help establish road weather management (RWM) as a core function. FHWA's Capability Maturity Framework (CMF) tool prompts agencies to develop action plans for implementing improved RWM capabilities. Capability maturity assessment is a first step towards greater mainstreaming of road weather management programs at State DOTs.

The framework was recently developed in 2014. Colorado DOT supported a validation exercise of the framework and various State and local agencies were part of the framework development process, but additional use of the framework is expected to occur in 2015 and beyond through facilitated workshops. Note that while not strictly for road weather, other capability assessments such as the American Association of State Highway and Transportation Officials (AASHTO) Capability Maturity Model (CMM) address issues relating to road weather management as well and have been used by many State DOTs as part of the Strategic Highway Research Program 2 (SHRP2) implementation process. While participation in these exercises is currently low, the RWMP anticipates that capability maturity exercises will increase and intends to track the participation levels in the coming years.

PM #18: Number of agencies that coordinate with their local forecast offices for road weather management and operations

Local weather forecast information is a critical input in road weather management and operations decision-making. When a State DOT makes an effort to coordinate with its National Weather Service (NWS) local forecast office, it reflects a commitment to enhancing the performance of road weather management and operations activities. This measure quantifies the number of agencies that are mainstreaming road weather management activities by coordinating with their local weather forecast offices, ranging from routine coordination to limited or no coordination.

The State DOT survey asked State DOTs to describe the extent of their coordination with the NWS local forecast office. Seventy-five percent of respondents reported at least some coordination with the NWS local forecast office. A small group of DOTs (7.5 percent) reported using publicly available information provided by the media and NWS, despite not having direct coordination, as illustrated in Figure 17.

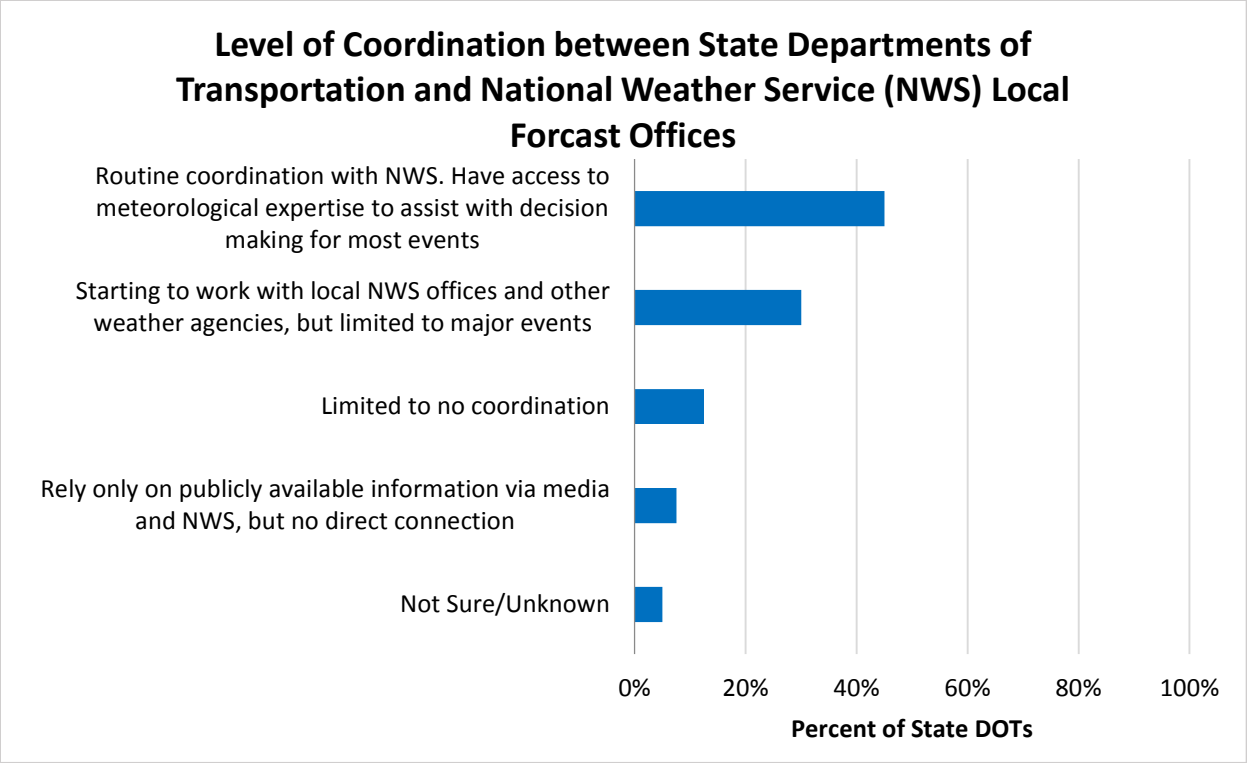

Figure 17. Graph. Level of Coordination between State Departments of Transportation and National Weather Service Local Forecast Offices for Road Weather Management and Operations Activities.

Summary

State DOTs are using a range of advisory, control, and treatment strategies as part of road weather management. Additionally, a large majority of agencies use local weather forecast information, either through routine coordination with the local NWS office or by accessing publicly available forecasts, to inform decision-making that allows for more effective strategy deployment. However, the RWMP has an opportunity to help advance the state of the practice by encouraging more States to conduct RWM capability maturity assessment exercises, which will help to further institutionalize RWM activities within agencies.

CHAPTER 9. OBJECTIVE 6: WEATHER-RELATED DECISION SUPPORT TECHNOLOGIES ARE INTEGRATED INTO TRAFFIC OPERATIONS AND MAINTENANCE PROCEDURES

The implementation of weather-related decision support technologies help State departments of transportation (DOT) deploy a more sophisticated approach to traffic operations and maintenance by factoring in the impact of adverse weather conditions. The performance measures (PM) under Objective 6 examine the various ways in which weather-related decision support technologies can be integrated into agency decision-making.

PM #19: Number of agencies adopting maintenance decision support systems technologies and methods

Evaluations of maintenance decision support systems (MDSS) technologies and methods have shown significant benefits to State and local agencies including cost savings on materials and labor, and improved highway operations. Adoption of MDSS indicates that more agencies are moving towards advanced approaches to managing their maintenance decisions and operations during winter seasons. Since 2004, the Road Weather Management Program (RWMP) has advocated the adoption of MDSS technology, and this performance measure captures the number of State DOTs that have adopted MDSS technologies and to what extent. The results of the 2015 State DOT survey are compared with the results from the 2012 update in Figure 18 below.

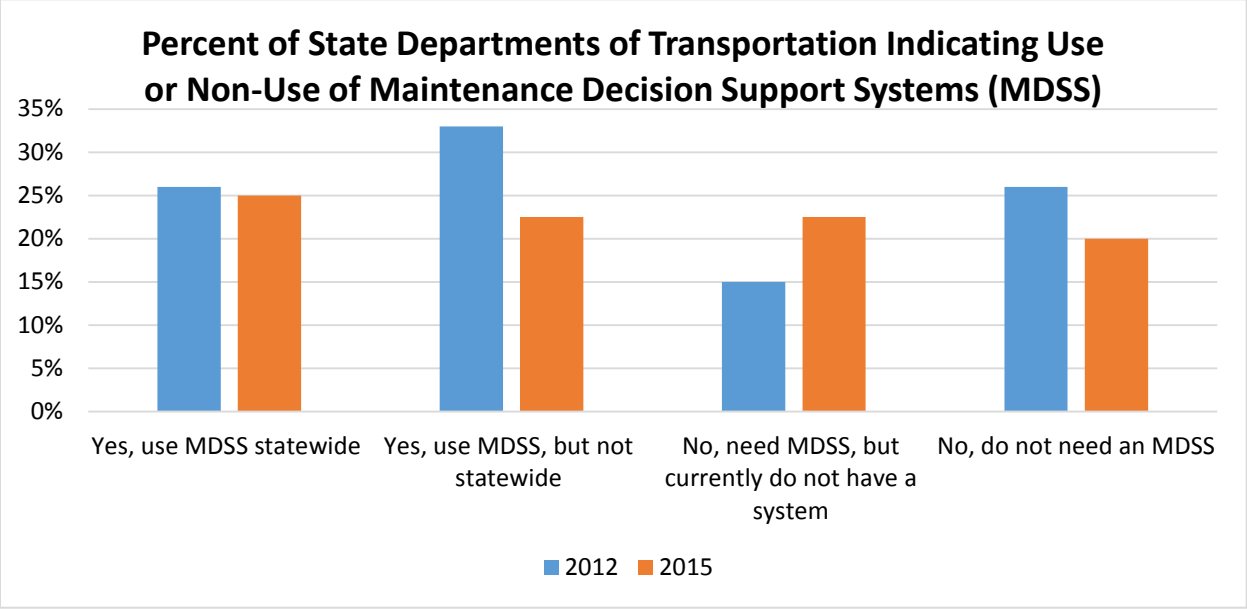

Figure 18. Graph. Percent of State Departments of Transportation Indicating Use or Non-Use of Maintenance Decision Support Systems.

The percentage of State DOTs with statewide MDSS deployment has remained constant, and partial MDSS use has decreased. Perhaps more significant is that the number of State DOTs expressing a need for MDSS increased, with a corresponding decrease in those agencies reporting no need for a system.

PM #20: Number of agencies using other weather-related decision-support tools

Weather-related decision-support tools help agencies increase the effectiveness of their road weather management practices. The array of tools available assists agencies and their staff in making more informed decisions. This performance measure captures the number of State DOTs employing operations decision support tools – other than MDSS – to respond to a range of weather conditions, beyond winter maintenance activities (i.e., snow and ice control), as captured in Figure 19.

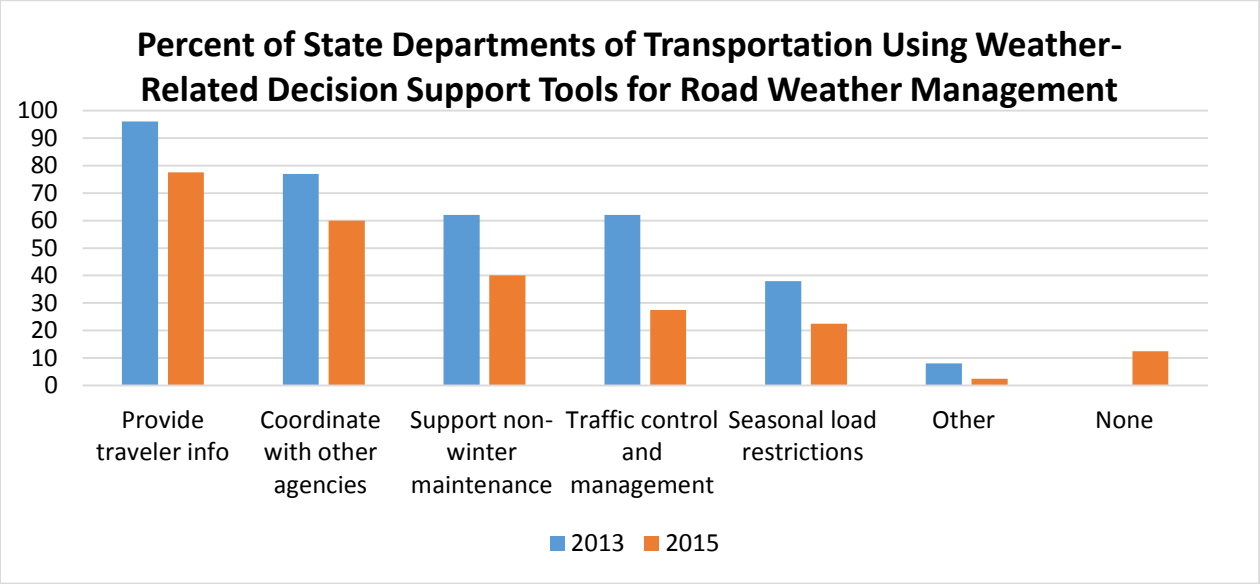

Figure 19. Graph. Percent of State Departments of Transportation Using Weather-Related Decision Support Tools for Road Weather Management.

Compared to 2013, the State DOTs respondents indicate an overall decrease in the use of weather-related decision support tools for road weather management, and a few states (12.5 percent) reported not using any tools. Despite the decrease in the use of decision support tools, the relative uses of the tools remain unchanged. Providing traveler information remains the most used tool, followed by coordination with other agencies, support of non-winter maintenance, traffic control and management, seasonal load restrictions and other.

PM #21: Number of agencies reporting use of appropriate analysis tools to factor weather impacts and strategies

Traditionally, traffic modeling and analysis tools have assumed perfect weather, making it difficult for an agency to adequately consider weather impacts and strategies. Increasingly, weather-responsive microscopic and mesoscopic traffic analysis and modeling tools are available to help agencies conduct more realistic traffic analyses. This measure shows the number of agencies employing analysis tools that consider adverse weather impacts and strategies.

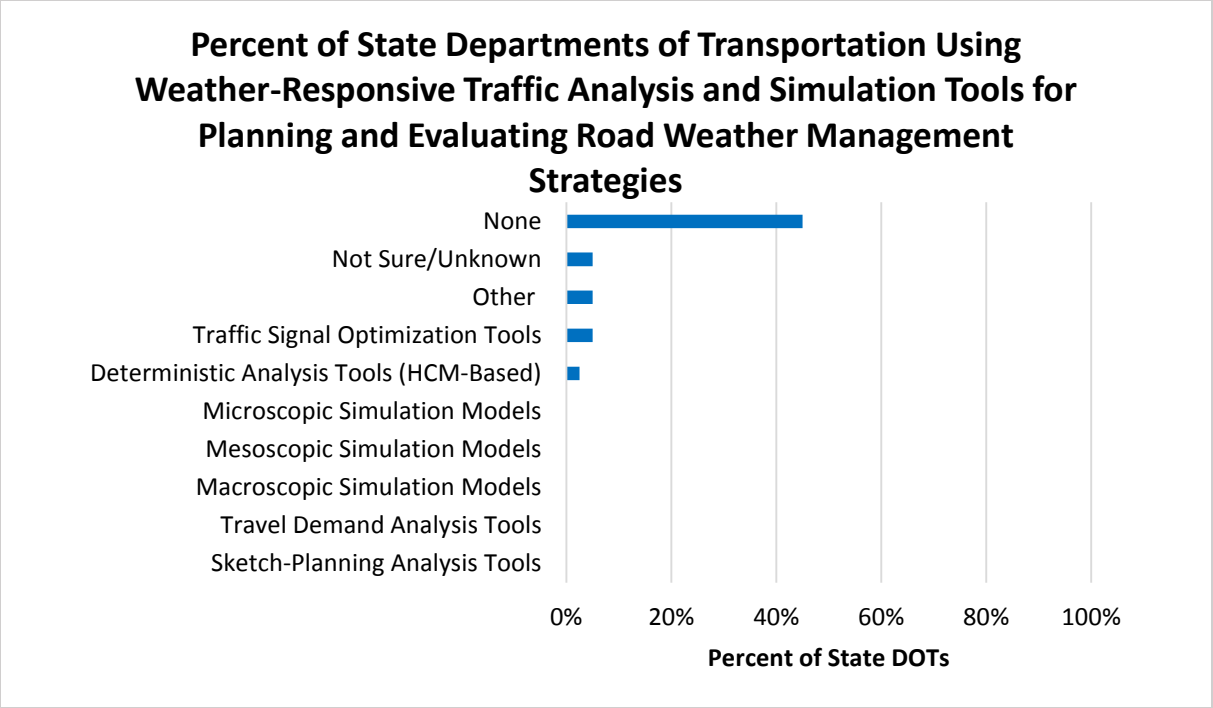

Figure 20. Graph. Percent of State Departments of Transportation Using Weather-Responsive Traffic Analysis and Simulation Tools for Planning and Evaluating Road Weather Management Strategies.

Results from the survey, shown in Figure 20, indicate that 50 percent of the respondents either did not use or were not aware of whether their agency used weather-responsive tools and models. This indicates greater use of these types of tools and models from the previous update, in which 83 percent of State DOTs responding indicated that their agency did not use weather-responsive tools and models.(35)

Of the types of tools and models identified, Traffic Signal Optimization Tools that factor in weather conditions are the most commonly used (5 percent), followed by Deterministic Analysis Tools (Highway Capacity Manual [HCM]-based). None of the State DOTs indicated using Microscopic Simulation Tools, Mesoscopic Simulation Tools, Macroscopic Simulation Tools, Travel Demand Analysis Tools, or Sketch Planning Analysis Tools.

Summary

The performance measures for this objective represent an opportunity for significant improvement. RWMP efforts in this area should focus on encouraging the use of MDSS and more sophisticated weather-responsive tools and models (analysis and modeling.), and increasing the availability and use of decision support tools other than MDSS.

[35] Further comparison to data from the previous survey is not possible, as the measure was defined differently in this update.

CHAPTER 10. OBJECTIVE 7: ADVANCE THE STATE OF THE PRACTICE BY RAISING ROAD WEATHER CAPABILITIES AND AWARENESS ACROSS THE TRANSPORTATION AND WEATHER COMMUNITIES

Professional development is critical to advancing the road weather management (RWM) state of the practice. To this end, the Road Weather Management Program (RWMP) provides resources to enhance the capabilities of both new and seasoned RWM practitioners. These activities include training courses and workshops, webinars to raise awareness of new research and resources, and the information and resources available on the RWMP website. The performance measures (PM) of objective 7 assess the effectiveness of RWMP's continuing efforts to support professional development of RWM practitioners.

PM #22: Number of agencies and attendees who have taken any of the training courses and workshops sponsored by the road weather management program

Training is a key approach to increasing knowledge and capabilities of the transportation community and supporting effective deployment of advanced road weather management strategies. RWMP offers several training and workshops on road weather management topics – both through agency-hosted events and partnerships with other transportation and weather agencies, including the Consortium for ITS Training and Education (CITE).

This performance measure shows the number of agencies and total number of attendees who have taken training courses or workshops sponsored by RWMP or offered in partnership with CITE. To a degree, this measures the usefulness and relevance of the course offerings to practitioners. Table 18 provides a list of the RWMP-sponsored training, and Table 19 includes a list of CITE-sponsored training.

Table 18. Road Weather Management Program-sponsored Training Courses and Workshops.

Course/Workshop	Date	Location	Attendees
Road Weather Equipment & Operations	July 2013	RWMP Stakeholder Meeting	22
Weather-Responsive Traffic Management	July 2013	RWMP Stakeholder Meeting	22
Kansas City Scout BCA Workshop	July 2014	Kansas City, Missouri	20
Tools for Road Weather Management Benefit/Cost Analysis	August 2014	RWMP Stakeholder Meeting	25
Interpreting Weather Products	August 2014	RWMP Stakeholder Meeting	25
Benefit-Cost Analysis Workshop	August 2014	RWMP Stakeholder Meeting	50
RWIS Applications and Future Trends	May 2015	ITS Las Vegas	16

Table 18. Road Weather Management Program-sponsored Training Courses and Workshops. (Continuation)

Course/Workshop	Date	Location	Attendees
Colorado DOT Capability Maturity Framework Workshop	December 2014	FHWA, 1 DOT, and Private Contractor	22
		Total Attendees	**202**

BCA – benefit/cost analysis
DOT – department of transportation
FHWA – Federal Highway Administration
ITS – intelligent transportation systems
RWIS – road weather information systems
RWMP – road weather management program

Table 19. Consortium for Intelligent Transportation Systems Training and Education-sponsored Training Courses and Workshops.

Course/Workshop	Date	Participating Agencies	Attendees
Principles and Tools for Road Weather Management	September 2013	FHWA, 11 State DOTs, and 1 Regional Planning Commission	19
RWIS Equipment and Operations	October 2013	FHWA, 11 State DOTs, 1 County, and 1 Private Contractor	18
Weather Responsive Traffic Management	April 2014	FHWA, 2 State DOTs, 1 City, and 1 Private Contractor	12
Principles and Tools for Road Weather Management	September 2014	FWHA, 5 State DOTs, 1 County, and 1 Private Contractor	9
RWIS Equipment and Operations	October 2014	FHWA, 5 State DOTs, and 1 County	7
		Total Attendees	**65**

DOT – department of transportation
FHWA – Federal Highway Administration
RWIS – road weather information systems

Between July 2013 and May 2015, there were 13 training courses and workshops held for transportation practitioners – eight were offered by RWMP, and five by CITE. A total of 267 attendees participated in this training. Participants included staff from State DOTs, local agencies, private consultants, and federal agencies.

PM #23: Number of agencies and participants in road weather management webinars led by the road weather management program

The RWMP has increasingly used webinars as an outreach tool to promote research results and raise awareness about the availability of guidance documents. In recent years, RWMP-led webinars have been hosted primarily by the Intelligent Transportation Systems (ITS) Professional Capacity Building Program (PCB) that targets a diverse stakeholder audience. All

PCB webinars are available free-of-charge, and the recordings are archived online.[36] This performance measure shows the number and affiliation of RWMP webinar participants, as shown in Table 20.

Table 20. Participation in Road Weather Management Program Webinars.

Event	Registration	Attendance	% of Attendance
Traffic Management during Flood Events (March 2014)	195	131	67.18
Performance Measures and BCA for WRTM (July 2014)	239	149	62.34
Use of Mobile Data for Weather Responsive Traffic and Maintenance Management (March, 2015)	199	102	51.25

BCA – benefit/cost analysis
WRTM – weather responsive traffic management

PM #24: Number of meetings, site visits, or venues where road weather management presentations/briefings were made

In addition to sponsoring events, RWMP representatives (staff and contractors) also provide presentations, briefings, and demonstrations at various meetings, site visits, or venues – extending the program's reach beyond its own activities. This performance measure shows the number of presentations on road weather management topics given by RWMP staff and contractors at non-RWMP-sponsored events. This measure indicates the broader presence that RWMP holds in the transportation and weather community. In the 2013-2014 timeframe, RWMP was represented by program staff or support contractors in the following meetings:

- 2013, 2014 Transportation Research Board (TRB) Annual Meeting.
- 2013, 2014 TRB Winter Maintenance Committee.
- 2013, 2014 TRB Surface Transportation Weather Committee.
- 2013, 2014 American Meteorological Society (AMS) Annual Meeting.
- 2013, 2014 AMS ITS Surface Transportation Committee.
- 2013, 2014 AMS Mobile Observations Subcommittee.
- 2013, 2014 AMS Open Environmental Information Systems Committee.
- 2013, 2014 AMS Washington Forum.
- 2013, 2014 AMS Summer Community Meeting.
- 2014 Intelligent Transportation Systems of America (ITSA) World Congress – Detroit, MI (Technical Showcase and TMC of the Future Demonstration).
- 2013 ITS World Congress – Tokyo, Japan.
- 2013, 2014 AASHTO Winter Maintenance Technical Service Program (WMTSP) 2013, 2014 OFCM Federal Plan Meeting.
- 2013, 2014 Office of the Federal Coordinator for Meteorology (OFCM) Committee on Integrated Observing Systems.

[36] USDOT, Office of the Assistant Secretary for Research and Technology, ITS-JPO, "ITS Professional Capacity Building Program – Advancing ITS Education." Available at: https://www.pcb.its.dot.gov/t3_webinars.aspx.

- 2013, 2014 Aurora Program.
- 2013, 2014 MDSS Pooled Fund Study.
- 2013, 2014 Clear Roads Pooled Fund Study.
- 2013, 2014 Clear Roads Technical Advisory Committee.
- 2013, 2014 World Road Association (PIARC) Winter Maintenance Spring Workshop.
- 2013, 2014 Cooperative Program for Operational Meteorology, Education and Training (COMET) Team Meeting.
- 2013, 2014 Board on Atmospheric Sciences and Climate (BASC, which is a part of National Academy of Sciences).
- 2013 National Rural ITS Conference.
- 2014 Data Palooza.
- 2014 Oregon Transportation Conference.
- 2014 Midwest Institute of Transportation Engineers (ITE) Meeting.
- 2014 Connected Vehicle Pilot Deployment Workshop.
- 2014 Evaluation of Low Cost Safety Improvements Pooled Fund Study.
- 2014 Automated Vehicles Symposium.
- 2014 Operations Council.
- 2013, 2014 National Oceanic and Atmospheric Administration's (NOAA) Office of Oceanic & Atmospheric Research (OAR).
- 2013, 2014 NOAA's National Weather Service (NWS).
- 2013, 2014 I-95 Corridor Coalition.
- 2014 I-95 Winter Weather Webinar.
- 2013, 2014 Crash Avoidance Metrics Partnership (CAMP).
- 2013, 2014 Vehicle Infrastructure Integration Consortium (VIIC).

In almost all of these meetings, program staff provided a presentation or an update on the program. The exact number of attendees at each presentation is unknown. As seen in previous iterations, the breadth of meetings that feature RWMP presentations, as well as consistent participation (i.e., multiple-year attendance) continues.

PM #25: Number of hits/visits to road weather management program website

The RWMP website is the primary source of information on the program and serves as an online repository for road weather management resources.[37] This performance measure captures the number of website hits, page views, and unique visitors to the RWMP website. Due to data archiving policies, limited data are available for the RWMP program website.

Table 21 compares website hits, page views, and visitors for two consecutive months (June and July) in 2012 and 2015. The data indicate an increase in RWMP website usage since 2012. Website hits more than doubled both months, and the website also experienced increases in unique page views and number of visitors.

[37] USDOT FHWA Office of Operations Road Weather Management Program. Available at: http://ops.fhwa.dot.gov/weather/.

Table 21. Road Weather Management Program Website Hits, Page Views, and Visitors.

	June 2012	June 2015	% Change	July 2012	July 2015	% Change
Website Hits	106,123	239,643	126%	143,613	295,626	105%
Page Views	7,641	11,422	49%	13,328	15,881	19%
Visitors	4,387	6,084	39%	4,963	7,239	45%

Furthermore, in 2013, a survey of attendees at the Road Weather Management Stakeholder Meeting indicated that the website was the most commonly used RWMP resource, which supports a high degree of awareness and use of the RWMP website.

Summary

Through webinars, workshops, meetings, and the program website, RWMP continues to make available various research products, best practices, and guidance to its stakeholders. As the program expands its knowledge and technology transfer efforts, greater coordination between the various activities under this objective can be achieved.

CHAPTER 11. OBJECTIVE 8: OPERATIONS COMMUNITY IS ENGAGED WITH CLIMATE CHANGE & SUSTAINABILITY COMMUNITIES

As climate changes, extreme weather and sustainability become more of a concern to State departments of transportation (DOT). The Road Weather Management Program (RWMP) continues to highlight the important role that transportation systems management and operations have in ensuring that current and future program effectiveness is maintained. In many ways, activities in this objective are geared towards mitigating the economic, environmental, and social risks of changes occurring to the transportation system. The following two performance measures (PM) provide an assessment of how State DOTs are viewing sustainability, climate change, and extreme weather.

PM #26: Number of public agencies meeting sustainability criteria related to road weather management

Sustainability is an area of increased interest to the Federal Highway Administration (FHWA), as evidence by the development and promotion of the INVEST online tool to help agencies incorporate sustainability principles into the transportation system. RWMP is gauging the use of INVEST and other sustainability criteria in road weather management. Specifically, for this performance measure, INVEST has criteria that agencies can score themselves against to track progress along sustainability and climate change initiatives.

In the State DOT survey, DOTs reported progress towards developing and implementing sustainability criteria related to road weather management as identified by the Infrastructure Voluntary Evaluation Sustainability Tool (INVEST). An overwhelming majority (95 percent) of State DOTs are pursuing some sort of sustainability effort related to road weather management. The most common sustainability activity among State DOTs is having a documented standard of practice or standard operation procedure (SOP) for snow and ice control. The least common is having a dedicated road weather management program, as illustrated in Figure 21.

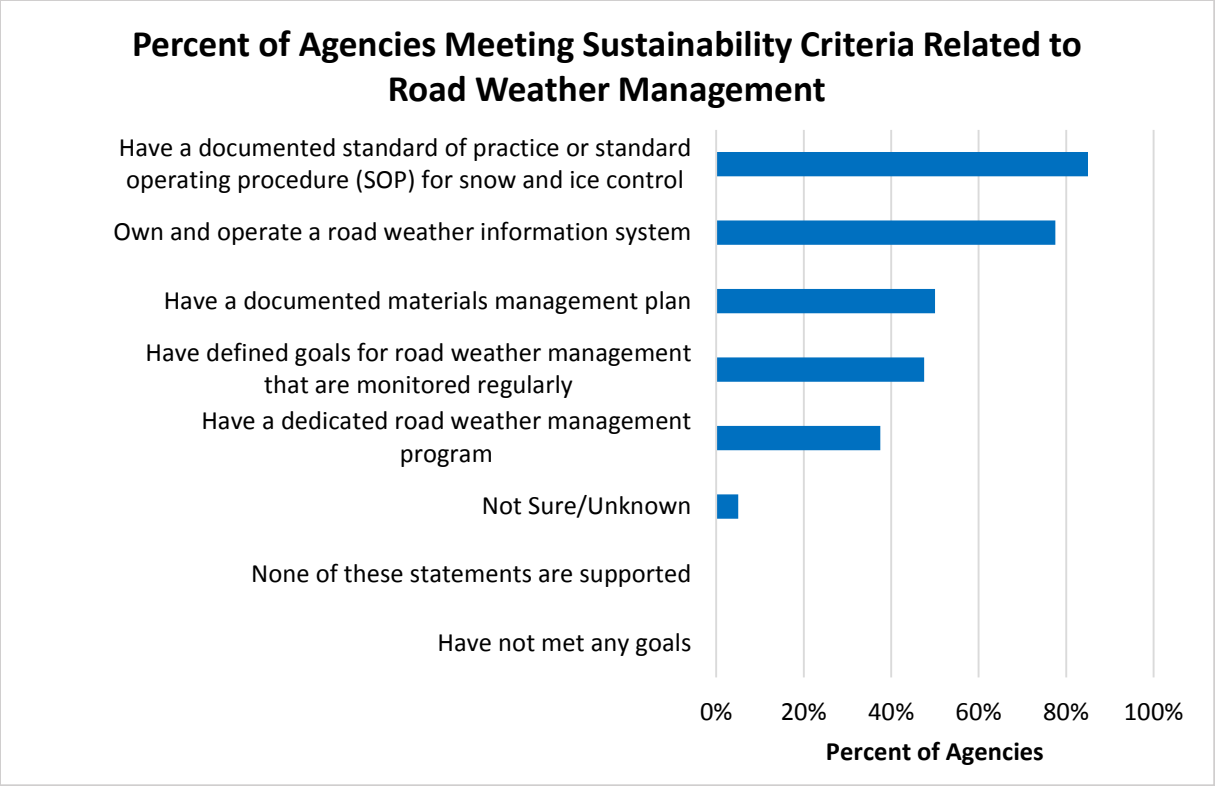

Figure 21. Graph. Percent of Agencies Meeting Sustainability Criteria Related to Road Weather Management.

PM #27: Number of agencies conducting vulnerability/risk assessments, developing/implementing resiliency plans or adaptation plans, for their road weather management infrastructure and processes to respond to climate change and extreme weather

This performance measure gauges the participation of State DOT operations and maintenance (O&M) groups in climate change adaptation activities in the region/State. This performance measure reflects an emerging area for RWMP pertaining to climate change and extreme weather. In the State DOT survey, agencies reported on their level of participation in extreme weather or climate change adaptation practices. The results, shown in Figure 22, support this is an emerging area of practice. Thirty-six percent expressed being uncertain about their State's activities related to climate change and extreme weather. However, there is some activity to report. Thirty one percent reported having developed/implemented process for responding to extreme weather.

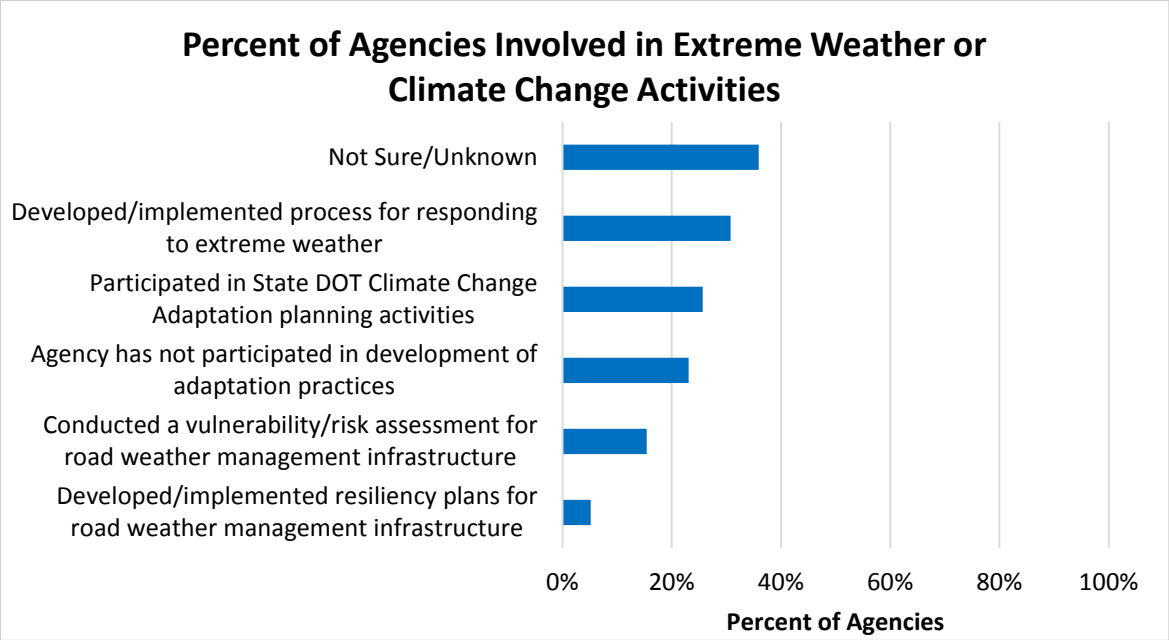

Figure 22. Graph. Percent of Agencies Involved in Extreme Weather or Climate Change Activities.

Summary

Overall, State DOTs, especially the northern-tier States, meet most of the programmatic criteria identified in INVEST. In general, States have plans to respond to extreme weather, but limited participation in broader efforts involving climate change within the State.

CHAPTER 12. CONCLUSION

Periodic assessments of the performance of transportation program activities and accomplishments have been a priority of the United States 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). Performance measures have been quantified on a biennial basis in 2010 and 2012. This report documents a comprehensive review of the existing measures and identifies new measures intended to fill gaps created by recent adjustments to the program in light of new legislation, emerging initiatives, and refinement of program goals and activities. The result is an updated performance assessment document tracking continued progress in meeting each of the RWMP objectives focused on activities occurring in the 2012-2015 timeframe.

The measures used to assess the performance of the RWMP reflect both quantifiable outputs (e.g., number of agencies that have acquired an maintenance decision support systems (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. However, other objectives, 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 promote the value of incorporating road weather data, tools, and research into State and local DOT 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 its activities in achieving these objectives in order to implement continuous improvement in their programs and strategies. The previous performance assessments 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.

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 do not 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 to State departments of transportation (DOT), and many do not yet include road weather into their metrics. The States focusing on measuring performance in managing their transportation system under weather conditions 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. 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. The update received responses from 40 State DOTs which is a significant increase from the previous update of 28 State responses highlighting the primacy of road weather among State DOT operational concerns.

The update includes a number of challenges also encountered in the previous 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 becomes 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.

Appendix A highlights some of the significant performance advances across all the measures.

CHAPTER 13. RECOMMENDATIONS

The following seven recommendations are offered based on the results of the performance measurements:

Catalog best practices in State departments of transportation (DOT) performance measurement and disseminate performance reports reported by State DOTs. An ongoing challenge is the limited amount of evaluation studies and performance reporting available. However, there is renewed interest in this area and several States are starting to report performance of winter maintenance operations. More importantly, the capability to collect and report on performance is also growing. A small initiative to compile performance measurement efforts by State DOTs and catalog the availability of such reports can spur further State DOT efforts in this important area.

Continue developing methodologies and case studies related to benefit-cost analysis for road weather management. State and local agencies are still struggling with calculating the returns on investments for their road weather management programs. Providing additional guidance and tools regarding benefit-cost assessments for road weather technologies and strategies should continue to be a priority for the program.

Improve tracking of participation and long-term outcomes of training, meetings and workshops. While challenging, tracking the effectiveness of Road Weather Management Program (RWMP) training and workshops is essential. Due to the diversity of forums by which RWMP promotes technical transfer, it is difficult to track how participants are using the information provided by the program. However, workshops for capability maturity frameworks have an action plan that needs to be developed as part of the process. Tracking progress of State DOTs in accomplishing the action plan is an easy first step towards gauging effectiveness of program sponsored workshops. Similarly, follow-up requests for additional guidance and support provided by the division offices or the resource centers after a program event are useful indicators of effectiveness.

Develop a knowledge and technology transfer effort to increase awareness of RWMP tools and resources. Information, products, and services provided by the program continue to grow. While the website is an effective tool for making them available to the broader community, it is a passive approach to disseminating the products of the program. A focused knowledge and technology transfer effort can take a coordinated approach to ensuring that research and development (R&D) initiatives and guidance developed by the program reach the intended stakeholders when they need it most. Greater integration with the activities of National Operations Center of Excellence (NOCoE) is a possible approach to initiate a more robust knowledge and technology transfer effort.

Develop program area focus around resilience and risk. Agencies are just starting to consider resilience as part of their planning for operations. Continuing the program's efforts in this area includes providing guidance, primers and a business case for resilience especially for road

weather management programs. The program needs to focus on establishing how agencies can factor in risk, uncertainty effectively in planning for road weather.

Continue to engage State DOTs around analysis, modeling and simulation tools. There is limited use of analysis, modeling, and simulation (AMS) tools in the road weather management community. Greater consideration, awareness and utilization of these tools can help plan, deploy and evaluate road weather management systems better. Easy-to-use and weather-responsive AMS tools are needed. While the program's R&D efforts have focused on building these tools, the next step needs to be in enabling adoption. Most agencies find that these tools are too cumbersome to set-up and use, expensive to maintain and require capabilities that may not exist within their workforce.

Support stakeholder interest in mobile data and connected vehicle applications. State DOTs are keenly interested in developing and deploying connected vehicle applications. The program should continue supporting the prototyping, deployment and evaluation of new connected vehicle applications that use mobile data effectively for road weather management.

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 Federal Highway Administration, State, Pooled Fund 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 into their operations, especially those States and agencies that have held back due to concerns with costs and risks. The evidence clearly 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. ASSESSING PERFORMANCE ADVANCES ACROSS OBJECTIVES

The following table provides a summary of the performance advances across the twenty-seven performance measures and the eight program objectives.

Table 22. Performance Advances across the Twenty-seven Performance Measures and the Eight Program Objectives.

Objectives	Performance Measures	Highlights	Assessment of Performance Measures
Objective 1: Build and sustain relationships with multi-disciplinary partners to expand RWM deployments	PM #1: Number of agencies participating in road weather R&D projects	• 4 State DOTs participated in the Pathfinder Project. • Seven public agencies have participated in the development and use of the RWMP Capability Maturity Framework. • 3 State DOTs have participated in the IMO program. • 7 State DOTs have been involved in V2I implementation activities. • 24 State DOTs have participated in weather data environment research activities. • 5 State DOTs have been involved in WRTM implementation support activities.	**Measure adequately captured** • R&D activities encompass all major initiatives of the RWMP, including the Pathfinder Project, RWMP Capability Maturity Framework, Weather Data Environment, IMO Program, V2I Application Development Efforts, and WRTM implementation support activities. • Data was collected through the FHWA RWMP via interviews with staff and review of the R&D program.

Table 22. Performance Advances across the Twenty-seven Performance Measures and the Eight Program Objectives. (Continuation)

Objectives	Performance Measures	Highlights	Assessment of Performance Measures
	PM #2: Number of agencies participating in, and benefiting from, road weather management stakeholder meetings/workshops	• The number of State DOTs attending the annual RWMP meetings has decreased with more than a 50 percent reduction over two years (2012 to 2014). However, the overall attendance in Stakeholder workshops is increasing with a greater proportion of private sector attendees. • Majority of participants expressed that the meetings and workshops met or exceeded their expectations and provided information that is useful and relevant to their duties.	**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. Now these meetings include annual RWMP stakeholder meetings and WRTM meetings held every two years. • In addition to States, other private and public agencies attend the stakeholder meetings. These agencies are not included in the measure, as this level of detail is not available for the earlier Clarus/MDSS meetings. • Data was collected from the FHWA RWMP records.
Objective 2: Ensure road weather management investments improve highway performance	PM #3: Number of agencies that collect and report road weather-related performance measures to the public	• Among the State DOTs surveyed, 23 DOTs reported regularly collecting and reporting some form of road weather performance measures. Eight States reported they did not collect and report road weather performance measures, and eight respondents were uncertain.	**Measure adequately captured for State DOTs** • This is a new measure. • Data was collected from the State DOT Survey. • Data shows that 58% of State DOTs report collecting performance measures.

Table 22. Performance Advances across the Twenty-seven Performance Measures and the Eight Program Objectives. (Continuation)

Objectives	Performance Measures	Highlights	Assessment of Performance Measures
	PM #4: Number of agencies that have a process for evaluating the ROI or net benefit of their road weather management investments	• The majority of States reported that they did not have a process or were not sure regarding evaluating ROI or the net benefits of road weather management investments. • Out of the respondents, five agencies do have a process in place.	**Measure adequately captured for State DOTs** • This is a new measure. • Data was collected from the State DOT Survey. • Data shows low level of ROI use for road weather management systems.
	PM #5: Reductions in agency costs of weather-related maintenance and operations activities	• Since the publication of the 2012 report, limited evaluation reports have been published documenting savings, but published case studies continued to show that winter maintenance costs decreased as the use of weather information increased or its accuracy improved. • Michigan DOT's benefit-cost calculations for deployment of RWIS and Maintenance Tracking using GPS were positive. • Idaho DOT's use of RWIS to monitor winter maintenance response has demonstrated significant reductions in winter maintenance costs.	**Measure captured to extent possible given available data** • National level statistics are annually reported, but individual case studies do not have a longitudinal aspect. • 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. • Data was collected from the Highway Statistics publication series (2001-2012), RITA ITS Benefits Database, and internet research for case studies.

Table 22. Performance Advances across the Twenty-seven Performance Measures and the Eight Program Objectives. (Continuation)

Objectives	Performance Measures	Highlights	Assessment of Performance Measures
	PM #6: Reduction in number and types of fatalities and crashes attributed to adverse weather nationally	• Although the national level data had been showing a decreasing trend of the number of fatal crashes occurring during inclement weather, 2013 shows a slight increase. • Practices such as variable speed management systems, ice warning systems, and automated anti-icing spray systems have demonstrated significant benefits. For example, in Colorado, implementation of a variable speed management system consisting of a complete RWIS, resulted in zero winter related crashes in one section of highway in Snowmass Canyon.	**Measure captured to extent possible given available data** • National level statistics are annually reported, but individual case studies do not have a longitudinal aspect. It is hard to determine the contribution of specific strategies on national crash rates that can be attributed to the RWMP. • Data was collected from FARS Database, NHTSA databases, Highway Statistics publication series (2001-2012), RITA ITS Benefits Database, and internet research for case studies.
	PM #7: Reduction in the extent of capacity losses and delays due to fog, snow, and ice events including freight	• Although limited evaluations have been found beyond those reported in 2012, systems have been implemented which demonstrated benefits on traffic flow. • One example came from Utah, which implemented a weather responsive signal control system. During severe winter weather events, travel times were improved by 3 percent and reduced overall stopped times by 14.5 percent.	**Measure captured to extent possible given available data** • Individual case studies do not have a longitudinal aspect. • National numbers for freight delays due to weather events are not readily available. • Data was collected via RITA ITS Benefits Database and internet research.

Table 22. Performance Advances across the Twenty-seven Performance Measures and the Eight Program Objectives. (Continuation)

Objectives	Performance Measures	Highlights	Assessment of Performance Measures
	PM #8: Increase in travel time reliability or decrease in variability due to road weather management strategies during adverse weather scenarios	• No new reliability-related studies for weather were found since 2012. • Very few agencies track reliability measures, and even the ones that do, do not distinguish between the various causes of reliability.	**Measure captured to extent possible given available data** • Individual case studies do not have a longitudinal aspect. • Data was collected via RITA ITS Benefits Database and internet research.
	PM #9: Reduction in the number of tons of salt or chemical usage in the U.S. normalized by Winter Severity Index	• The use of a Winter Severity Index (WSI) has continued to gain recognition as a way to gauge the relative severity of winter weather across various time frames or geographic regions. • Idaho DOT has reported a significant reduction in winter maintenance costs due to the use of a winter mobility index.	**Measure captured to extent possible given available data** • While national numbers for salt use are available, normalizing salt use by State for evaluation purposes is a challenge. • Data was collected from the USGS Minerals Yearbook: Salt (2006-2013), Salt Institute, AASHTO Standing Committee on Maintenance, RITA ITS Benefits Database, and internet research.

Table 22. Performance Advances across the Twenty-seven Performance Measures and the Eight Program Objectives. (Continuation)

Objectives	Performance Measures	Highlights	Assessment of Performance Measures
Objective 3: (Advance) Transportation, weather, and research communities' use of and reliance on fixed and mobile road weather observations	PM #10: Number of State DOTs that are participants in the MADIS program	• 12 States have participated in the MADIS program as of April 2015.	**Measure adequately captured** • This is a new measure. • The transition from *Clarus* to MADIS is a new activity since the 2012 update. The RWMP is supporting NOAA by working with State DOTs to secure data sharing agreements and helping to ensure data quality by integrating quality checking algorithms into the system. • Data was collected from the RWMP records.
	PM #11: Number of State DOTs that subscribe to road weather products and services	• Results show that subscription to National Weather Service Products held steady since 2013.	**Measure adequately captured for State DOTs**
	PM #12: Number of State DOTs collecting mobile observations of road weather data from appropriate vehicle fleets	• Overall, 50 percent of States surveyed collect real-time field data from maintenance vehicles. • Results of the survey show that collecting data fleet-wide is starting to become a practice; as many as three DOTs reported using 100 percent of the fleet to collect data, compared to zero in 2013.	**Measure adequately captured from State DOTs** • Major activities/projects of interest for this update included: IMO, VDT Research, and DMA. • Data was collected from State DOT Survey.

Table 22. Performance Advances across the Twenty-seven Performance Measures and the Eight Program Objectives. (Continuation)

Objectives	Performance Measures	Highlights	Assessment of Performance Measures
	PM #13: Number of State DOTs reporting the use of ESS in operations and maintenance activities	• In the State DOT survey, the respondents reported a total of 2,473 ESS, which is a slight decrease from the previous update. • Ninety-five percent of State DOTs reported using ESS data for decision-making. Majority of agencies also use ESS data to provide current conditions to traveler information systems (61 percent) and input for segment-level forecasts (58 percent).	**Measure adequately captured from State DOTs** • There is a slight change in definition in measure which makes it hard to fully compare with previous results. Previous updates tracked only the number of ESS sensors. • Data was collected from ITS Deployment Statistics and State DOT Survey.
Objective 4: Advance the state-of-the-art for mobile sensing and integrating vehicle data into road weather applications	PM #14: Number of/percentage of responding agencies using mobile data-based applications in road weather management	• Fifty-eight percent of States are considering applications to leverage data collected from mobile platforms. • Twenty-three percent of States have developed applications that input real-time data from vehicle fleets. • Five percent have developed applications that utilize data derived from vehicle fleets and vehicle-to-infrastructure connectivity.	**Measure adequately captured from State DOTs** • This is a new measure. • Data was collected from State DOT Survey. • Data shows strong interest but low level of current capability.

Table 22. Performance Advances across the Twenty-seven Performance Measures and the Eight Program Objectives. (Continuation)

Objectives	Performance Measures	Highlights	Assessment of Performance Measures
Objective 5: Advance the state-of-the-practice by promoting tailored management strategies for different regions	PM #15: Number of States disseminating weather advisory and other road weather information to travelers	• After significant increases between 2004 and 2007, the use of websites/social media and DMS steadied around the same level in 2015. • There was a significant increase in the use of 511 to disseminate information to travelers, while the use of HAR decreased. • Overall, providing road condition information on DMS is more prevalent, followed by agency hosted social media and other mobile applications. Road condition information on DMS and HAR are the most widely deployed.	**Measure adequately captured from State DOTs** • Data was collected from ITS Deployment Statistics and State DOT Survey. • Trends have plateaued but a large number of responding states provide information to travelers during adverse weather. After significant increases between 2004 and 2007, the use of websites/social media and DMS steadied around the same level in 2015.
	PM #16: Number of agencies using control and treatment strategies during weather events	• The most widely deployed strategy, either partially or statewide, is employing traffic incident management practices (83 percent). • The least commonly used strategy is ramp meter adjustment (20 percent).	**Measure adequately captured from State DOTs** • Data was collected and State DOT Survey.

Table 22. Performance Advances across the Twenty-seven Performance Measures and the Eight Program Objectives. (Continuation)

Objectives	Performance Measures	Highlights	Assessment of Performance Measures
	PM #17: Number of agencies that have participated in or conducted RWM capability maturity assessment exercises	• The framework was recently developed in 2014. While participation in these exercises is currently low, the RWMP anticipates that capability maturity exercises will increase and intends to track the participation levels in the coming years.	**Measure adequately captured** • This is a new measure. Future updates will be able to track this measure over time. • Data was collected from RWMP records.
	PM #18: Number of agencies that coordinate with their local forecast offices for road weather management and operations	• 75 percent of respondents reported at least some coordination with the NWS local forecast office. • Nearly 8 percent of DOTs reported using publicly available information provided by the media and NWS, despite not having direct coordination.	**Measure adequately captured from State DOTs** • This is a new measure. Future updates will be able to track this measure over time. • Data was collected from State DOT Survey. • Data shows strong linkages with NWS among responding States DOTs.
Objective 6: Weather-related decision support technologies are integrated into traffic operations and maintenance procedures	PM #19: Number of agencies adopting MDSS technologies and methods	• The percentage of State DOTs with statewide MDSS deployment has remained constant, and partial MDSS use has decreased. • Perhaps more significant is that the number of State DOTs expressing a need for MDSS increased, with a corresponding decrease in those agencies reporting no need for a system.	**Measure adequately captured from State DOTs** • Data was collected from State DOT Survey. • MDSS use has stayed constant but program emphasis on MDSS adoption as decreased. Perhaps more significant is that the number of State DOTs expressing a need for MDSS increased, with a corresponding decrease in those agencies reporting no need for a system.

Table 22. Performance Advances across the Twenty-seven Performance Measures and the Eight Program Objectives. (Continuation)

Objectives	Performance Measures	Highlights	Assessment of Performance Measures
	PM #20: Number of agencies using other weather-related decision-support tools	• Respondents indicate an overall decrease in the use of weather-related decision support tools for road weather management, and a few states (12.5 percent) reported not using any tools • Providing traveler information remains the most used tool, followed by coordination with other agencies, support of non-winter maintenance, traffic control and management, and seasonal load restrictions.	**Measure adequately captured from State DOTs** • Respondents indicate an overall decrease in the use of weather-related decision support tools for road weather management, and a few states (12.5 percent) reported not using any tools. • Data was collected from State DOT Survey.
	PM #21: Number of agencies reporting use of appropriate analysis tools to factor weather impacts and strategies	• 50 percent of the respondents either did not use or were not aware of whether their agency used weather-responsive tools and models, which is less than the previous update, indicating an increased use of these types of tools and models.	**Measure adequately captured from State DOTs** • Potential for more widespread use of these models and tools for weather-related applications. Currently very low capabilities and interest to use analysis, modeling and simulation tools for weather • Data was collected from State DOT Survey.

Table 22. Performance Advances across the Twenty-seven Performance Measures and the Eight Program Objectives. (Continuation)

Objectives	Performance Measures	Highlights	Assessment of Performance Measures
Objective 7: Advance the state-of-the-practice by raising road weather capabilities and awareness across the transportation and weather communities	PM #22: Number of agencies and attendees who have taken any of the training courses and workshops sponsored by the RWMP	• Between July 2013 and May 2015, there were 13 training courses and workshops held for transportation practitioners – eight were offered by RWMP, and five by CITE. • A total of 267 attendees participated in these training courses. Participants included staff from State DOTs, local agencies, private consultants, and federal agencies.	**Measure adequately captured** • Training is a key approach to increasing knowledge and capabilities of the transportation community and supporting effective deployment of advanced road weather management strategies. • Data was collected from FHWA RWMP records (for stakeholder meetings) and attendance records from CATT Lab.
	PM #23: Number of agencies and participants in road weather management webinars led by the RWMP	• Three RWMP webinars have been held in 2014-2015. • 382 people have participated in the RWMP webinars.	**Measure adequately captured** • The RWMP has increasingly used webinars as an outreach tool to promote research results and raise awareness about the availability of guidance documents. • Data was collected from the ITS PCB Program records and other webinar sponsors/venues.

Table 22. Performance Advances across the Twenty-seven Performance Measures and the Eight Program Objectives. (Continuation)

Objectives	Performance Measures	Highlights	Assessment of Performance Measures
	PM #24: Number of meetings, site visits or venues where road weather management presentations/briefings were made	• In the 2013-2014 timeframe, RWMP was represented by program staff or support contractors in nearly 60 meetings. • The breadth of meetings that feature RWMP presentations, as well as consistent participation (i.e., multiple-year attendance) continues.	**Measure adequately captured from State DOTs** • RWMP representatives (staff and contractors) also provide presentations, briefings, and demonstrations at various meetings, site visits, or venues – extending the program's reach beyond its own activities. • This measure indicates the broader presence that RWMP holds in the transportation and weather community. • Data was collected from FHWA RWMP.
	PM #25: Number of hits/visits to RWMP website	• Limited website statistics indicate significant increase in RWMP website use.	**Measure adequately captured from State DOTs** • Data was collected from FHWA RWMP.
Objective 8: Operations community is engaged with climate change & sustainability communities	PM #26: Number of public agencies meeting sustainability criteria related to road weather management	• DOTs reported progress towards developing and implementing sustainability criteria related to road weather management as identified by INVEST. • An overwhelming majority (95 percent) of State DOTs are pursuing some sort of sustainability effort related to road weather management. • The most common sustainability activity among State DOTs is having a documented standard of practice or SOP for snow and ice control. The least common is having a dedicated road weather management program.	**Measure adequately captured from State DOTs** • This measure is being quantified differently than prior update. • Data was collected from the State DOT Survey. • DOTs reported progress towards developing and implementing sustainability criteria related to road weather management as identified by INVEST.

Table 22. Performance Advances across the Twenty-seven Performance Measures and the Eight Program Objectives. (Continuation)

Objectives	Performance Measures	Highlights	Assessment of Performance Measures
	PM #27: Number of agencies conducting vulnerability/risk assessments, developing/implementing resiliency plans or adaptation plans, for their road weather management infrastructure and processes to respond to climate change and extreme weather	• The results support this is an emerging area of practice. • 36 percent expressed being uncertain about their State's activities related to climate change and extreme weather. • 31 percent reported having developed/implemented process for responding to extreme weather.	**Measure adequately captured from State DOTs** • This is a new measure. • Data was collected from the State DOT Survey. • The results support this is an emerging area of practice.

AASHTO – American Association of State Highway and Transportation Officials
CATT – Center for Advanced Transportation Technology
CITE – Consortium for ITS Training and Education
DMA – dynamic mobility application
DMS – dynamic message sign
DOT – department of transportation
FARS – Fatality Analysis Reporting System
FHWA – Federal Highway Administration
GPS – global position system
HAR – Highway Advisory Radio
IMO – integrated mobile observations
INVEST – Infrastructure Voluntary Evaluation Sustainability Tool
ITS – intelligent transportation systems
MADIS – Meteorological Assimilation Data Ingest System
MDSS – maintenance decision support systems
NHTSA – National Highway Traffic Safety Administration
NOAA – National Oceanic and Atmospheric Administration
NWS – National Weather Service
PCB – professional capacity building
PM – performance measure
R&D – research and development
RITA – Research and Innovative Technology Administration
ROI – return on investment
RWIS – road weather information systems
RWM – road weather management
RWMP – road weather management program
SOP – standard operating procedures
USGS – United States Geological Survey
V2I – vehicle to infrastructure
VDT – vehicle data translator
WRTM – weather responsive traffic management
WSI – winter severity index

APPENDIX B. STATE DEPARTMENT OF TRANSPORTATION SURVEY SUMMARY

The following pages show the State DOT survey questions and summary.

Table 23. State Department of Transportation Survey Question 4 and Associated Responses.

Q4. What are your agency's sources of weather and road weather information?
Associated PM: Number of State DOTs that subscribe to road weather products and services

Answer Options	Response Percent	Response Count
USGS Earthquake alerts	0.0%	0
Not Sure/Unknown	0.0%	0
Other	15.4%	6
National Sensor Data Sources (MADIS)	20.5%	8
FAA (ASOS, AWOS)	35.9%	14
Public/Social Media	41.0%	16
Private Weather Service Providers	71.8%	28
Agency field personnel	79.5%	31
Agency sensors (RWIS/Probes)	92.3%	36
National Weather Service Products	100.0%	39

Answered Question	**39**
Skipped Question	**1**

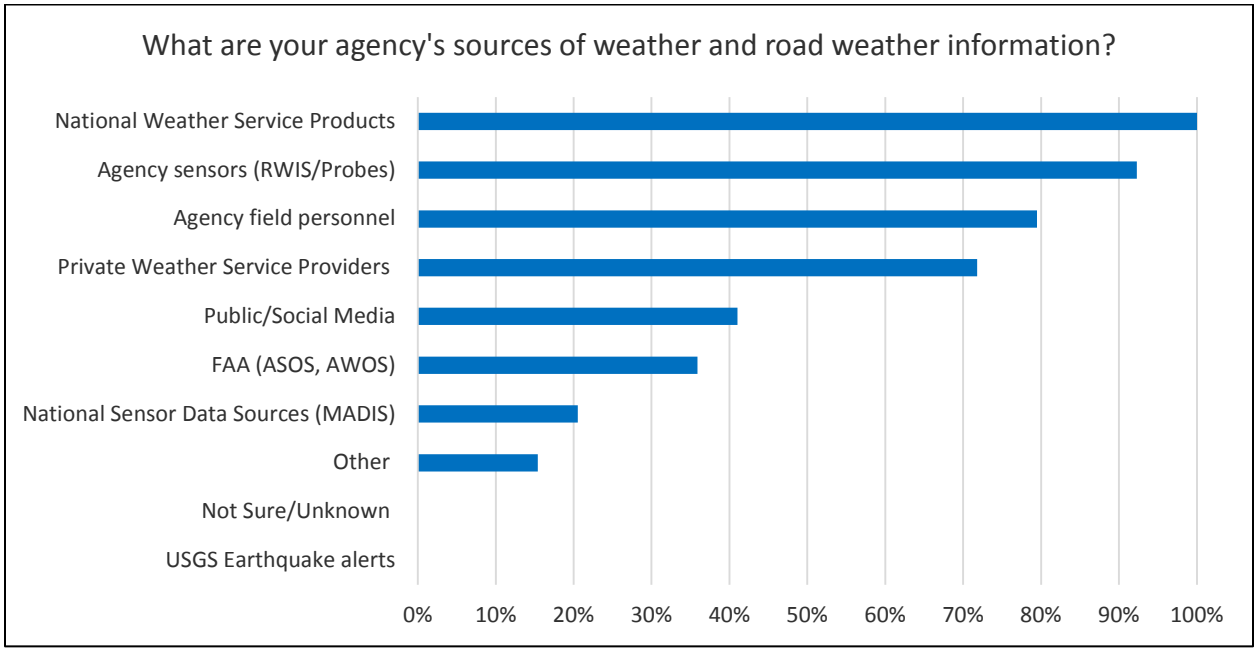

Figure 23. Chart. Responses from State Department of Transportation Survey Question 4.

Other responses to Question 4 included:

- MDSS;
- DOT/Highway;
- Mobile weather sensors (air temp, road temp, Relative Humidity, dew point, etc.);
- PFS MDSS;
- Internet websites and applications; and
- The Lyndon State College Meteorological Department.

Table 24. State Department of Transportation Survey Question 5 and Associated Responses.

Q5. Does your agency collect real-time field data from maintenance vehicles?

Associated PM: Number of State DOTs collecting mobile observations of road weather data from appropriate vehicle fleets

Answer Options	Response Percent	Response Count
Yes	50.0%	20
No	50.0%	20
Answered Question		**40**
Skipped Question		**0**

Table 25. State Department of Transportation Survey Question 6 and Associated Responses.

Q6. If you answered "Yes" to question #5, which of the following data are collected from maintenance vehicles, and from what percentage of the applicable fleets?

Associated PM: Number of State DOTs collecting mobile observations of road weather data from appropriate vehicle fleets

Answer Options	100%	At least 50% but less than 100%	At least 25% but less than 50%	Less than 25%	Not Collected	Not Sure/ Unknown
Plow Status and Material Usage	3	5	2	7	2	1
Atmospheric weather data (air temperature, relative humidity, etc.)	2	5	1	8	3	1
Road weather conditions data (pavement temperature, etc.)	2	5	1	8	3	1
Answered Question	**20**					
Skipped Question	**0**					

Table 26. State Department of Transportation Survey Question 7 and Associated Responses.

Q7. Has your agency developed applications or tools that rely on availability of real-time mobile data from vehicle fleets and/or vehicle-to-infrastructure connectivity?

Associated PM: Number of/percentage of responding agencies using mobile data-based applications in road weather management

Answer Options	Percentage
Not Sure/Unknown	15.0%
Developed applications that use both real-time data from vehicle fleets and vehicle-to-infrastructure connectivity	5.0%
Developed applications that use real-time data from vehicle fleets	22.5%
Considering applications in either area, but not yet developed	57.5%

Answered Question	**40**
Skipped Question	**0**

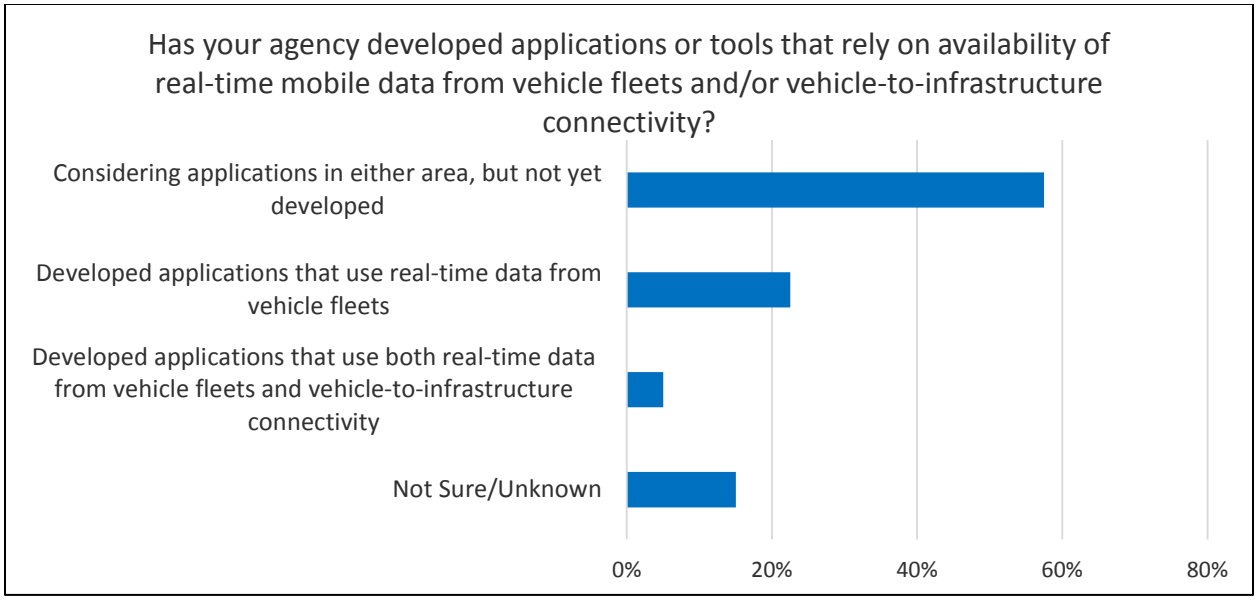

Figure 24. Chart. Responses from State Department of Transportation Survey Question 7.

Table 27. State Department of Transportation Survey Question 8 and Associated Responses.

Q8. How many environmental sensor stations (ESS) does your state agency operate statewide?
Associated PM: Number of State DOTs reporting the use of ESS in operations and maintenance activities

Total number	**2473**
Answered Question	**40**
Skipped Question	**0**

Table 28. State Department of Transportation Survey Question 9 and Associated Responses.

Q9. Describe how you use your ESS (Check all that apply).
Associated PM: Number of State DOTs reporting the use of ESS in operations and maintenance activities

Answer Options	Percentage
Not Sure/Unknown	5.3%
Other	7.9%
Use ESS data as input for segment-level forecasts	57.9%
Use ESS data to provide current conditions to traveler information systems	60.5%
Use ESS data to support traffic management and maintenance decision-making	94.7%

Answered Question	**38**
Skipped Question	**2**

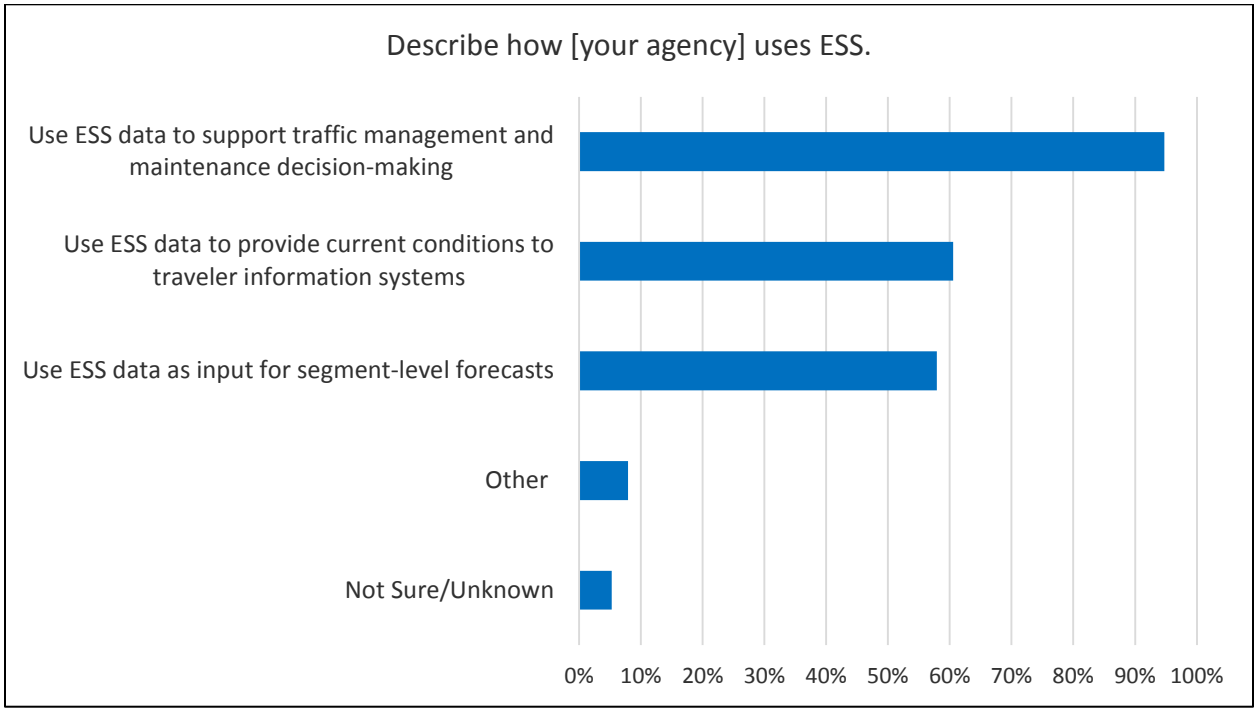

Figure 25. Chart. Responses from State Department of Transportation Survey Question 9.

Another response to Question 9 included “mobile.”

Table 29. State Department of Transportation Survey Question 10 and Associated Responses.

Answer Options	Deployed Statewide (or in all applicable locations)	Limited or Partial Deployment	Not Yet Deployed	Not Sure/ Unknown
Atmospheric weather information on dynamic message signs	10.0%	25.0%	55.0%	10.0%
Road condition information on highway advisory radio	27.5%	27.5%	35.0%	10.0%
Road condition information on agency-hosted social media (Twitter, Facebook, etc.) or mobile applications	55.0%	22.5%	15.0%	7.5%
Road condition information on dynamic message signs	45.0%	42.5%	12.5%	0.0%
Road condition information on agency hosted websites or 511 phone systems	80.0%	10.0%	7.5%	2.5%

Answered Question **40**
Skipped Question **0**

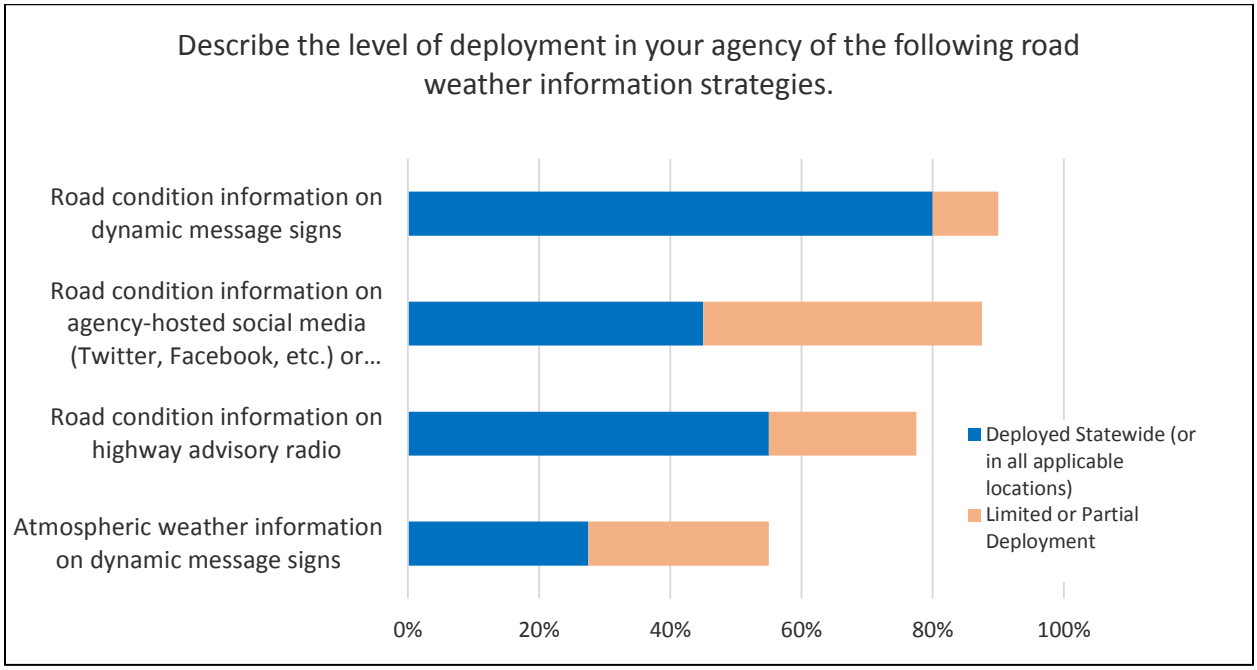

Figure 26. Chart. Responses from State Department of Transportation Survey Question 10.

Table 30. State Department of Transportation Survey Question 11 and Associated Responses.

Q11. Describe the level of deployment in your agency of the following weather responsive traffic management strategies.
Associated PM: Number of agencies using control and treatment strategies during weather events

Answer Options	Deployed	Limited or	Not Yet	Not Sure/

	Statewide (or in all applicable locations)	Partial Deployment	Deployed	Unknown
Adjust ramp meters	5.0%	15.0%	70.0%	10.0%
Adjust traffic signal timing	0.0%	30.0%	55.0%	15.0%
Employ variable speed limits	7.5%	37.5%	52.5%	2.5%
Deploy ITS to determine need to implement temporary restrictions on vehicles	27.5%	32.5%	35.0%	5.0%
Deploy ITS to manage traffic diversions in response to road closures)	47.5%	32.5%	15.0%	5.0%
Employ traffic incident management practices	45.0%	37.5%	15.0%	2.5%
Answered Question	**40**			
Skipped Question	**0**			

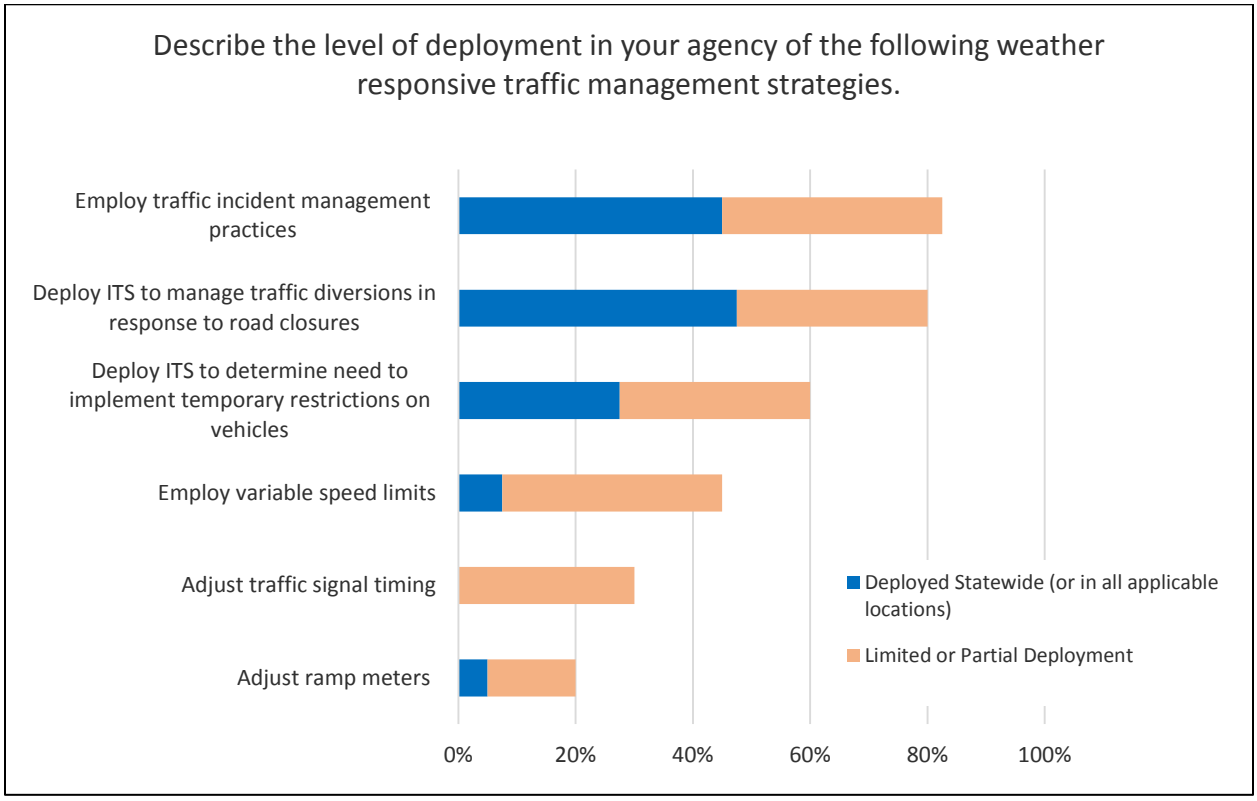

Figure 27. Chart. Responses from State Department of Transportation Survey Question 11.

Table 31. State Department of Transportation Survey Question 12 and Associated Responses.

Q12. Describe your level of interaction with the National Weather Service local forecast offices for road weather management and operations activities.
Associated PM: Number of agencies that coordinate with their local forecast offices for road weather management operations

Answer Options	Percentage
Not Sure/Unknown	5.0%
Rely only on publicly available information via media and NWS, but no direct connection	7.5%
Limited to no coordination	12.5%
Starting to work with local NWS offices and other weather agencies, but limited to major events	30.0%
Routine coordination with NWS. Have access to meteorological expertise to assist with decision making for most events	45.0%

Answered Question 40
Skipped Question 0

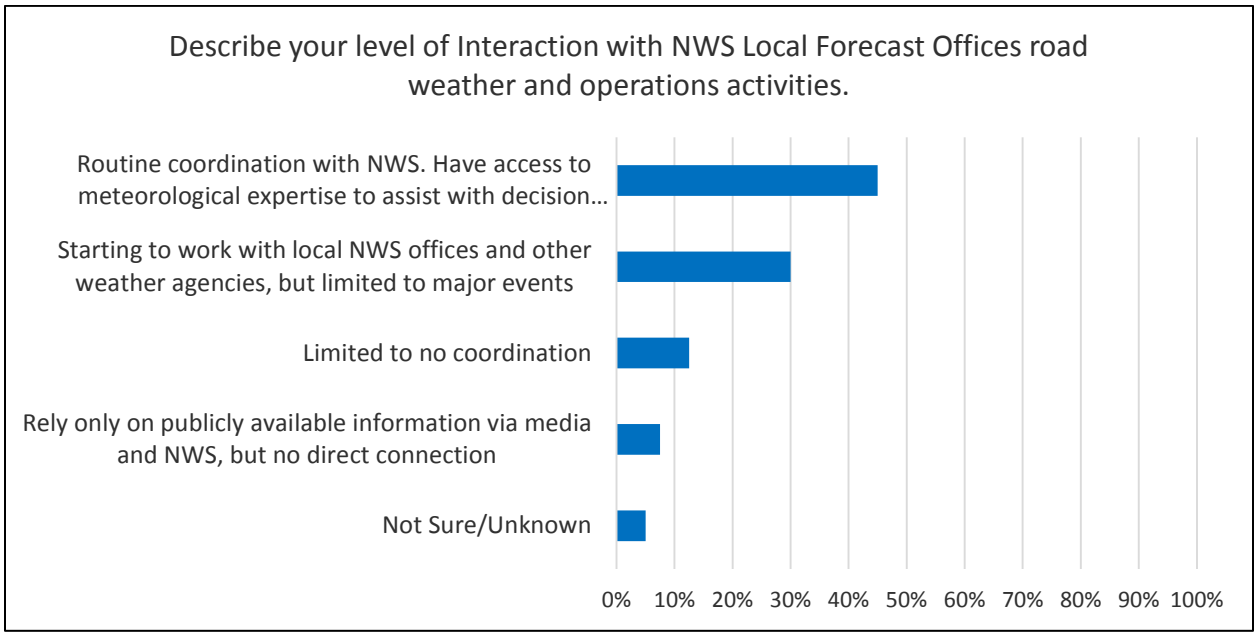

Figure 28. Chart. Responses from State Department of Transportation Survey Question 12.

Table 32. State Department of Transportation Survey Question 13 and Associated Responses.

Q13. Does your agency use a winter Maintenance Decision Support System (MDSS) for snow and ice control? A winter MDSS includes software that provides strategic and tactical weather forecasts, supports treatment decision making and provides summary reports of weather event performance.
Associated PM: Number of agencies adopting MDSS technologies and methods

Answer Options	Percentage
Not Sure/Unknown	10.0%
No- do not need an MDSS.	20.0%
Yes- use an MDSS, but not statewide.	22.5%
No- need an MDSS, but currently do not have a system.	22.5%
Yes- use an MDSS statewide.	25.0%
Answered Question	**40**
Skipped Question	**0**

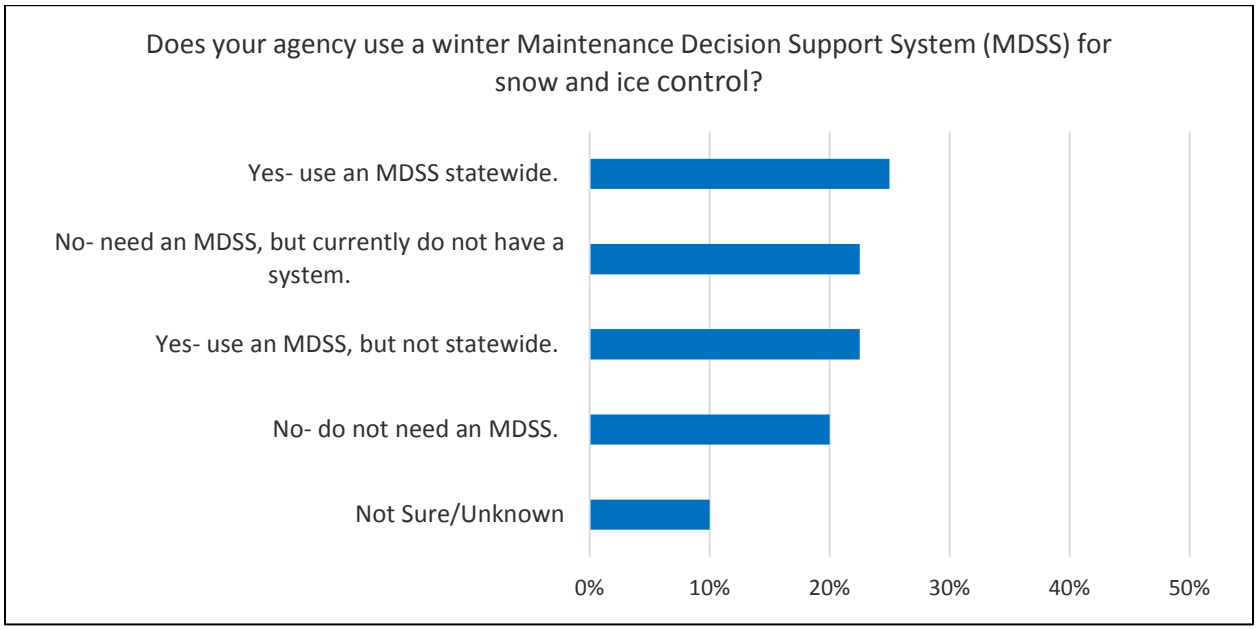

Figure 29. Chart. Responses from State Department of Transportation Survey Question 13.

Table 33. State Department of Transportation Survey Question 14 and Associated Responses.

Q14. Does your agency use other decision support tools (besides a winter MDSS) for road weather management. If yes, what are these tools use for? (Check all that apply) Associated PM: Number of agencies reporting use of appropriate analysis tools to factor weather impacts and strategies

Answer Options	Percentage
Other	2.5%
Not Sure/Unknown	7.5%
None	12.5%
Setting seasonal load restrictions	22.5%
Traffic control and management (e.g., speed limit determination, signal timing plans, ramp metering rates)	27.5%
Supporting non-winter maintenance activities (e.g., maintenance scheduling, construction coordination)	40.0%
Coordination with other jurisdictions/agencies	60.0%
Providing traveler information	77.5%
Answered Question	**40**
Skipped Question	**0**

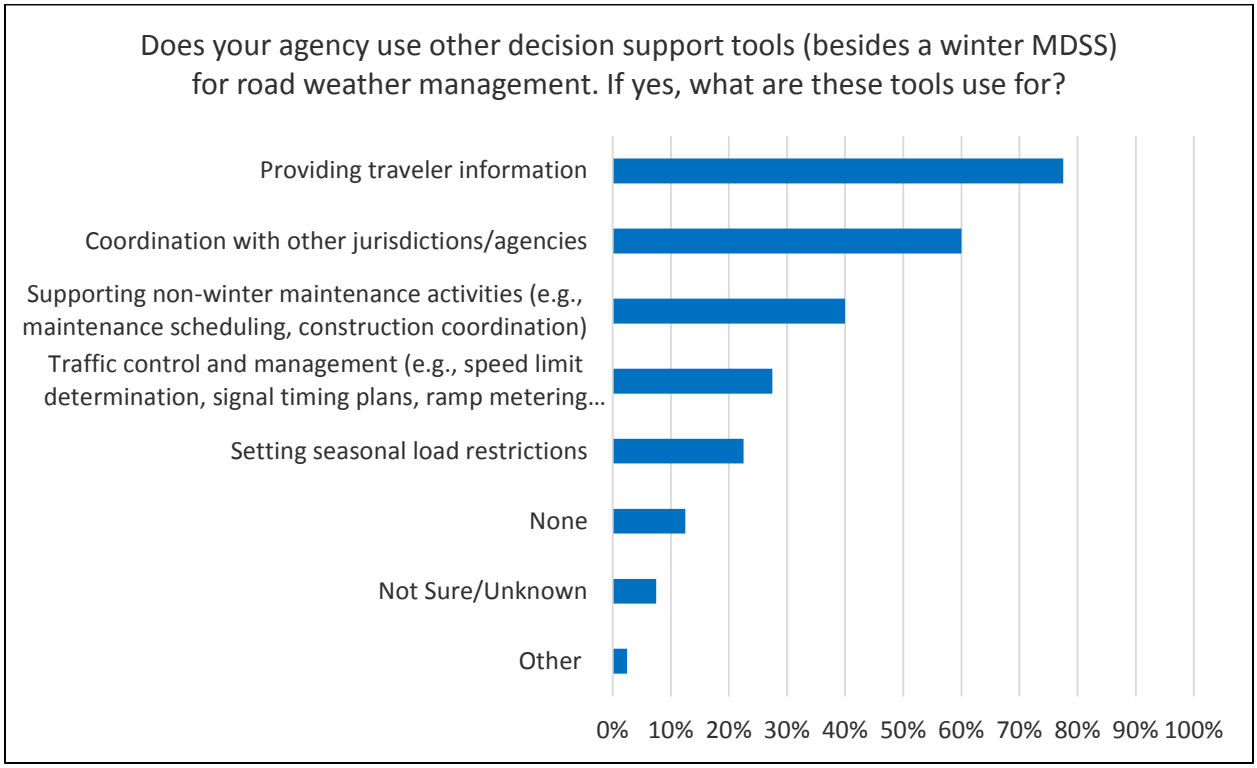

Figure 30. Chart. Responses from State Department of Transportation Survey Question 14.

Another response to Question 14 included "material/labor use tracking, VSL only experimental at this time (Iowa)."

Table 34. State Department of Transportation Survey Question 15 and Associated Responses.

Q15. What types of traffic analysis and simulation tools does your agency use for planning and evaluating road weather management strategies?
Associated PM: Number of agencies reporting use of appropriate analysis tools to factor weather impacts and strategies

Answer Options	Percentage
Sketch-Planning Analysis Tools	0.0%
Travel Demand Analysis Tools	0.0%
Macroscopic Simulation Models	0.0%
Mesoscopic Simulation Models	0.0%
Microscopic Simulation Models	0.0%
Deterministic Analysis Tools (HCM-Based)	2.5%
Traffic Signal Optimization Tools	5.0%
Other	5.0%
Not Sure/Unknown	5.0%
None	45.0%
Answered Question	**40**
Skipped Question	**0**

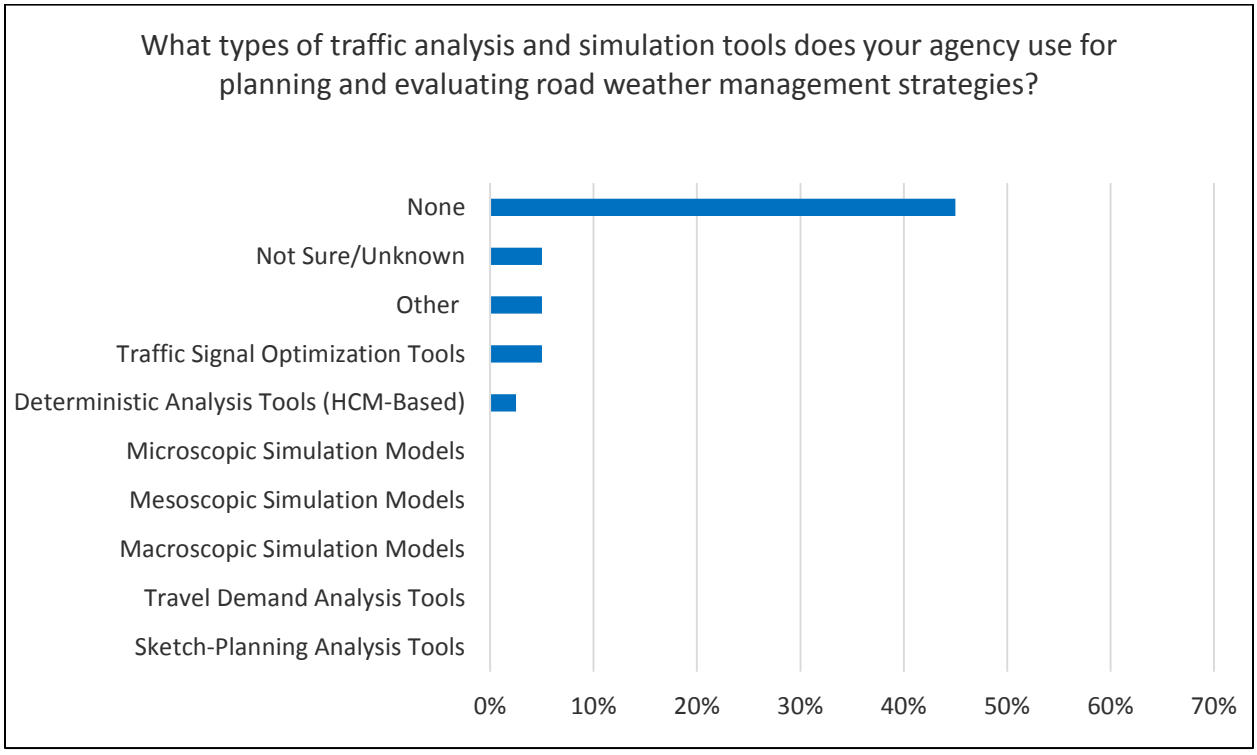

Figure 31. Chart. Responses from State Department of Transportation Survey Question 15.

Table 35. State Department of Transportation Survey Question 16 and Associated Responses.

Q16. Road weather management supports sustainable transportation systems. Which statements below pertain to your agency. (Check all that apply.)

Associated PM: Number of public agencies meeting "INVEST" and/or sustainability criteria related to road weather management

Answer Options	Percentage
Have not met any goals	0.0%
None of these statements are supported	0.0%
Not Sure/Unknown	5.0%
Have a dedicated road weather management program	37.5%
Have defined goals for road weather management that are monitored regularly	47.5%
Have a documented materials management plan	50.0%
Own and operate a road weather information system	77.5%
Have a documented standard of practice or standard operating procedure (SOP) for snow and ice control	85.0%
Answered Question	**40**
Skipped Question	**0**

Criteria	Percentage
5	18%
4	20%
3	23%
2	28%
1	8%
Not Sure	5%

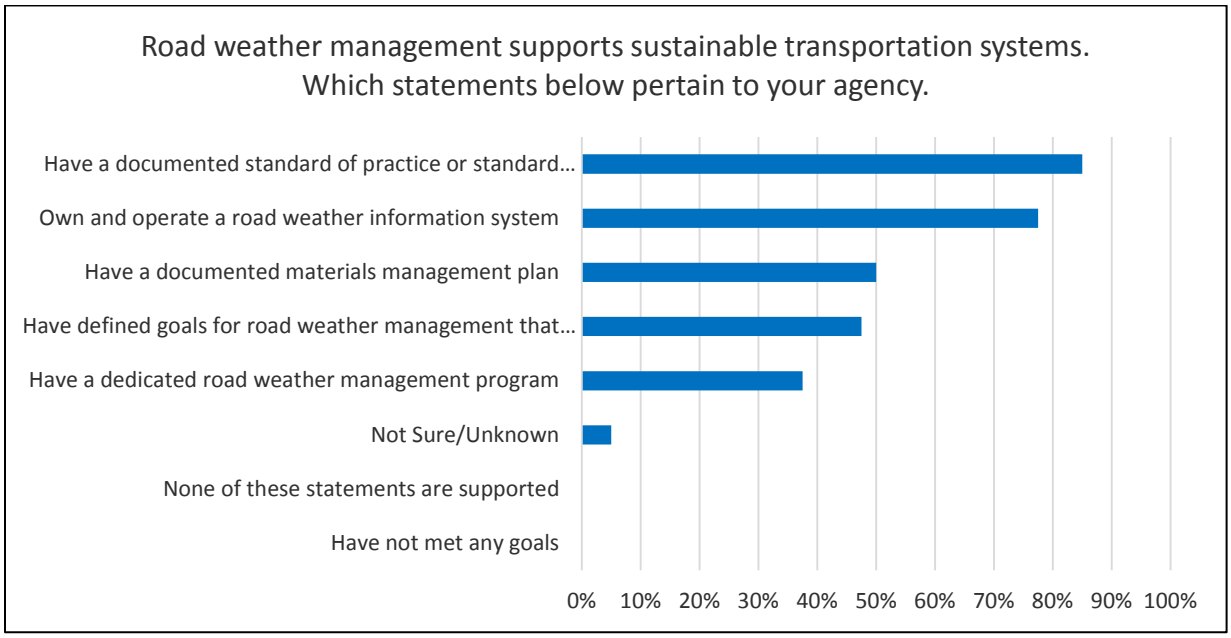

Figure 32. Chart. Responses from State Department of Transportation Survey Question 16a.

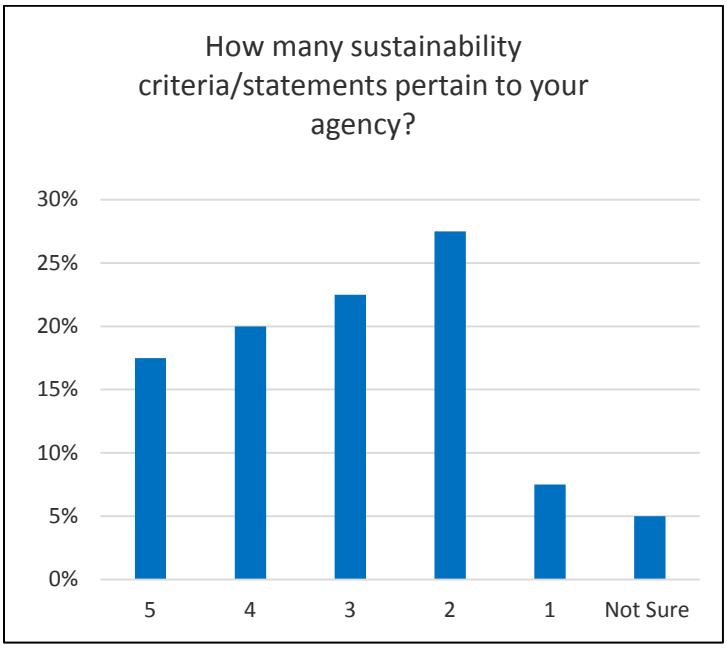

Figure 33. Chart. Responses from State Department of Transportation Survey Question 16b.

Table 36. State Department of Transportation Survey Question 17 and Associated Responses.

Q17. Has your agency participated in extreme weather or climate change adaptation practices? (Check all that apply.)
Associated PM: Number of agencies conducting vulnerability/risk assessment or developing/implementing resiliency plans, for their road weather management infrastructure and processes to respond to climate change and extreme weather; Number of agencies participating in State DOT Climate Adaptation activities sponsored by the FHWA and its partners

Answer Options	Percentage
Developed/implemented resiliency plans for road weather management infrastructure	5.1%
Conducted a vulnerability/risk assessment for road weather management infrastructure	15.4%
Agency has not participated in development of adaptation practices	23.1%
Participated in State DOT Climate Change Adaptation planning activities	25.6%
Developed/implemented process for responding to extreme weather	30.8%
Not Sure/Unknown	35.9%

Answered Question	**39**
Skipped Question	**1**

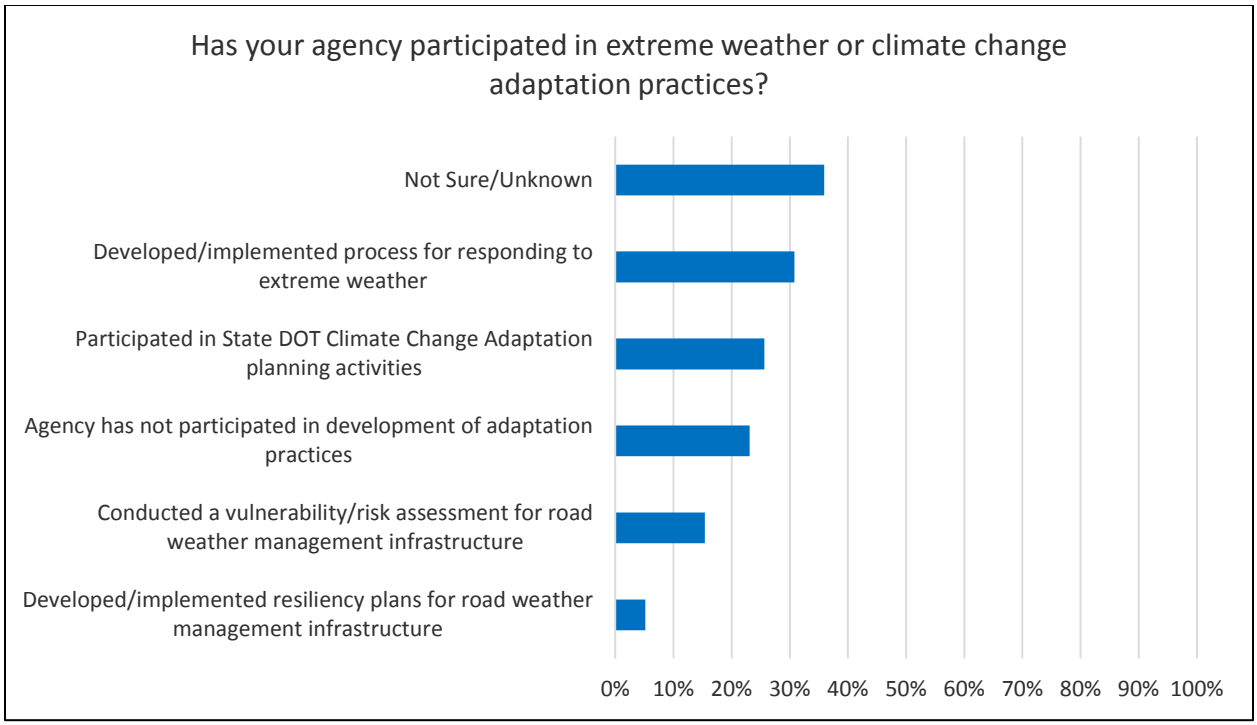

Figure 34. Chart. Responses from State Department of Transportation Survey Question 17.

Table 37. State Department of Transportation Survey Question 18 and Associated Responses.

Q18. Does your agency regularly collect and report road weather performance measures? (This may include dashboards, winter maintenance reports, seasonal summaries, etc.)

Associated PM: Number of agencies that collect and report road weather related performance measures to the public (i.e. winter severity index, mobility index, etc.)

Answer Options	Percentage
Yes	59.0%
No	20.5%
Not Sure/Unknown	20.5%

Answered Question	**39**
Skipped Question	**1**

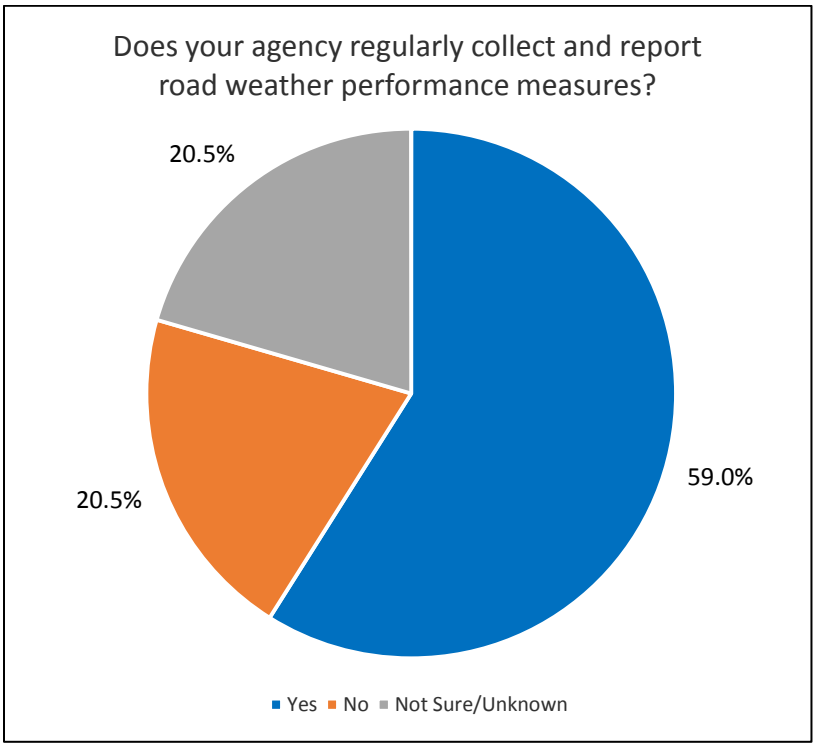

Figure 35. Chart. Responses from State Department of Transportation Survey Question 18.

Table 38. State Department of Transportation Survey Question 19 and Associated Responses.

Q19. Does your agency have a process for evaluating the return on investment (ROI) or net benefits of road weather management investments?

Associated PM: Number of agencies that have a process for evaluating the return on investment (ROI) or net benefit of their road weather management investments

Answer Options	Number
Yes	5
No	24
Not Sure/Unknown	10

Answered Question	**39**
Skipped Question	**1**

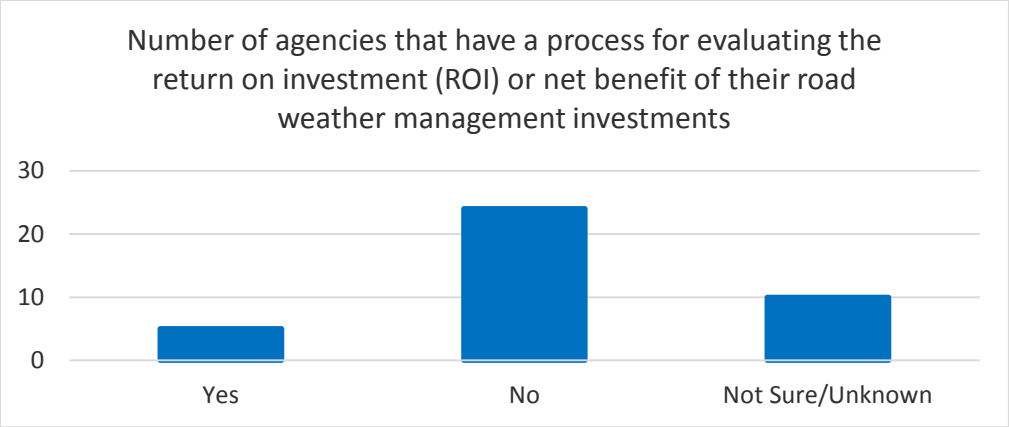

Figure 36. Chart. Responses from State Department of Transportation Survey Question 19.

Table 39. State Department of Transportation Survey Question 20 and Associated Responses.

Q20. Would you be willing to participate in the next update of this survey?
Associated PM: Number of agencies that have a process for evaluating the return on investment (ROI) or net benefit of their road weather management investments

Answer Options	Percentage
Yes	97.4%
No	2.6%
Not Sure/Unknown	0.0%

Answered Question	**39**
Skipped Question	**1**

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