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Federal Highway Administration

2017
ROAD WEATHER MANAGEMENT PERFORMANCE MEASURES UPDATE

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16. Abstract The Federal Highway Administration's Road Weather Management Program (RWMP) assesses its progress toward meeting programmatic objectives through established performance measures. Assessments have been completed and documented in 2009, 2012, and 2015, and this update is the next iteration of this periodic review. While previous updates reported each performance measure individually, this report used an alternative approach to present the results to convey a general and more concise evaluation of the RWMP's progress and success by mapping the performance measures to at least one of the following categories: (1) road weather management impacts, (2) application of road weather management tools and technologies, (3) road weather management capacity building, and (4) partnerships and stakeholder collaboration. Overall, the 2017 report presents the latest results of the RWMP's performance measures, highlights significant changes or improvements from the last update, and lists recommendations on future focus areas for the RWMP. The report also serves as a resource and outreach product to further advance the importance and widespread implementation of road weather technologies.			
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Table of Contents

List of Figures

List of Figures (continued)

List of Tables

List of Acronyms

ASOS	Automated Surface Observing System
AWOS	Automated Weather Observing System
BCA	benefit-cost analysis
CITE	Consortium for ITS Training and Education
CMF	Capability Maturity Framework
CV	connected vehicle
CV-WRTM	Connected Vehicle-Enabled Weather Responsive Traffic Management
DOT	department of transportation
EDC	Every Day Counts
ESS	environmental sensor station
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
GPS	global position system
IMO	Integrated Mobile Observations
IMRCP	Integrated Modeling of Road Condition Prediction
INVEST	Infrastructure Voluntary Evaluation Sustainability Tool
I2V	infrastructure-to-vehicle
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
PM	performance measure
R&D	research and development
RW	road weather
RWIS	Road Weather Information Systems
RWM	road weather management
RWMP	Road Weather Management Program
TRB	Transportation Research Board
USDOT	United States Department of Transportation
USGS	United States Geological Survey
V2I	vehicle-to-infrastructure
VMT	vehicle miles traveled
WDE	Weather Data Environment
WRTM	weather responsive traffic management

Executive Summary

More than a decade ago, the Federal Highway Administration's (FHWA) Road Weather Management Program (RWMP) established a set of performance measures to assess its program effectiveness in improving the performance of the transportation system during adverse weather conditions. Since then, assessments of the performance measures have been completed and documented in 2009, 2012, and 2015. Over the years, the program has aimed to maintain overall consistency in the types of performance measures to allow for a more complete, long-term assessment of a program. However, additional performance measures were added in 2015 to address some gaps due to changes in program objectives and recent advances in road weather management capability and technology. As a result, 27 performance measures were evaluated in 2015. This update maintained the same performance measures to assess the RWMP's success in meeting its programmatic objectives. The current objectives that guide the RWMP's activities and direction include:

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

Assessing performance measures allows the RWMP to evaluate its progress, gather information regarding the state of the practice and national capabilities in road weather management, and identify any areas that need more focus, support, or outreach. The resulting report presents the progress, successes, and overall vision of the RWMP and serves as a potential resource and communication product to further advance the importance and widespread implementation of road weather technologies.

In the past, performance measure updates simply reported on each performance measure individually. For this update, the performance measures were classified into at least one of four categories, as described below, in order to convey a general and more concise evaluation of the RWMP's progress and success.

ROAD WEATHER MANAGEMENT IMPACTS

This report describes the recent practices and performance measures related to mitigating the mobility, safety, economic, and productivity impacts of adverse weather conditions. The study team found that, while there is an enhanced level of awareness and interest in understanding the performance of transportations systems under adverse weather and the effects of road weather management strategies, State departments of transportation (DOTs) are still figuring out how best to collect and report this information. Some examples include publishing winter maintenance reports, providing online dashboards, calculating a winter severity index, and developing a process for evaluating the return on investment of road weather strategies.

As expected, snow and ice removal expenditures and salt usage fluctuate due in large part to the natural, unpredictable variation in weather conditions. Even so, a few States have demonstrated promising examples of how nationwide salt usage and related removal expenditures can be better controlled as a result of innovative road weather management strategies such as Road Weather Information System (RWIS) installations, dashboards, and salt management plans. Reducing the delays experienced by travelers driving in inclement weather conditions is a key element of system performance improvement targeted by the RWMP. Since the last performance measures update, two additional noteworthy delay-reducing strategies were identified as being used by States: Michigan's Weather Responsive Traveler Information System, Wx-TINFO, and Utah's Pathfinder Team. Finally, while the adverse weather crash trend has been downward over the last 15 years, it is hard to attribute them directly to a particular road weather management strategy.

APPLICATION OF ROAD WEATHER MANAGEMENT TOOLS AND TECHNOLOGIES

The first set of road weather management tools examined pertains to the collection of fixed and mobile road weather observation data, which can be made available in real-time or archived. The number of State DOTs using such systems since the previous report has decreased for some tools, but increased for the majority of tools assessed, suggesting an overall slight improvement in this objective.

The research ream also tracked the use of vehicle-to-infrastructure (V2I) applications, infrastructure-to-vehicle (I2V) applications, and connected vehicle technologies. State DOTs are in the early stages of developing applications or tools that leverage I2V or V2I connectivity, with only 17 percent of agencies reporting having done so.

The percentage of State DOTs with Maintenance Decision Support System (MDSS) deployments has shown a slight decrease, and there was an increase in the number of States saying that they do not need an MDSS. Ninety-five percent of State DOT survey respondents either did not use or were not aware of whether their agency used weather-responsive analysis, modeling, and simulation tools.

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.). When assessing road weather management performance from this angle, it is clear that, nationwide, State DOTs are making improvements. More agencies are deploying road weather information dissemination strategies, such as publicizing atmospheric weather and road condition information on dynamic messaging signs, as well as road condition information on agency-hosted social media or mobile applications. There is also a reported increase in the number of States deploying more automated, innovative traffic control strategies for ramp meters, traffic signal timing, and variable speed limits.

Sustainability for road weather management has largely been restricted to having a snow and ice removal policy. Since the last update, the percentage of agencies reporting they have a dedicated road weather management program has not grown, although the percentage of agencies implementing plans for road weather management infrastructure and developing various processes for extreme weather has increased.

ROAD WEATHER MANAGEMENT CAPACITY BUILDING

This report contains an evaluation of how the RWMP is providing stakeholders with flexible, accessible learning and growth opportunities through training, technical assistance, and resources. Overall, participation in RWMP stakeholder meetings has been consistent and strong since the last update. The number of agencies participating in RWMP Regional Roundtables (webinars) has also increased. Unfortunately, the Consortium for ITS Training and Education (CITE) reported a decline in registration for RWMP-related online courses.

Developed in 2014, FHWA's Road Weather Management Capability Maturity Framework (CMF) evaluation model and tool prompts agencies to select actions and develop plans for raising their RWM capabilities based on an evaluation of the State's current capabilities. At the time this report was written, 10 States and regions have already conducted Road Weather Management CMF workshops and identified capability improvement actions.

The RWMP informs and educates various stakeholders through public meetings, conferences, and other events. From 2015 to mid-2017, representatives from the RWMP have attended or presented at more than 20 events throughout the country and abroad.

PARTNERSHIPS AND STAKEHOLDER COLLABORATION

The RWMP is collaborating and partnering with public and private stakeholders through various activities. Information sharing and collaboration are fundamental to road weather management implementation and success. One way RWMP is achieving this is by partnering with State and local transportation agencies to advance various research and development (R&D) projects, such as Pathfinder, Road Weather Management CMF, Weather Data Environment, and the Integrated Mobile Observations Program. Overall, the number of States that are conducting at least one R&D activity has increased by more than 50 percent from the last performance measure update.

The RWMP also supports the National Oceanic and Atmospheric Administration (NOAA) by encouraging State DOTs to share data and ensure data quality by integrating quality checking algorithms into their systems. Participation in NOAA's Meteorological Assimilation Data Ingest System (MADIS) program is tracked by the number of State DOTs that have signed a data sharing agreement. From 2016 to 2017, the participation of State DOTs has increased by 75 percent. The level of coordination between State DOTs and the National Weather Service has also greatly increased since the last assessment.

CONCLUSIONS

Overall, performance measurement continues to be important for the RWMP. These performance assessments provide direction for the program as they work to advance road weather strategies. Based on the results of this 2017 update, the following recommendations are identified for consideration by the RWMP:

- Create a national database of State DOT performance measures and reports.
- Re-engage in MDSS outreach.
- Continue to showcase value of V2I application deployment.
- Develop a plan for accelerating awareness and deployment of weather-responsive traffic analysis tools.
- Support Weather Savvy Roads (WSR) interest and implementation plans.

The current update of the performance measures continues to show an engaged stakeholder community, new and strengthened partnerships, and sustained use of available technologies for road weather management. Interest among the stakeholder community in performance measurement, V2I deployment, and WSR offers new opportunities for the program to engage and encourage new State DOTs and partners to be part of these national road weather management activities.

Chapter 1. Introduction

Since 2006, the Federal Highway Administration's (FHWA) Road Weather Management Program (RWMP) has conducted a periodic assessment of program effectiveness in improving the performance of the transportation system during adverse weather conditions. Assessments of program performance were conducted and documented in 2009, 2012, and 2015.[1,2,3] These updates reviewed program initiatives and major accomplishments; assessed the continued suitability, strengths, and weaknesses of existing measures for evaluating program performance; and incorporated new measures, as appropriate, that reflected current and future program initiatives. The *2017 Road Weather Management Performance Measures Update* is a continuation of this periodic review of the RWMP's performance and an update to the 2015 report.

OBJECTIVES OF REPORT

The performance measures update and associated reports allow the RWMP to evaluate its progress and effectiveness in accomplishing its goals and to assess the Nation's overall capability with respect to road weather management. The report also serves as a resource and outreach product to further advance the importance and widespread implementation of road weather technologies. This assessment helps to communicate the overall success of the RWMP and identify areas that need more focus, support, or outreach. The 2017 report presents the latest results of the RWMP's performance measures, highlights significant changes or improvements from the last update, and lists recommendations on future focus areas for the RWMP.

ROAD WEATHER MANAGEMENT PROGRAM GOALS, OBJECTIVES, AND KEY PRODUCTS

The RWMP strives to better understand the ways weather impacts roads and to promote successful strategies and tools to mitigate those impacts. In broad terms, the program achieves its goals through stakeholder coordination; road weather research and development; technology transfer, training, and education; and performance management and evaluation. The RWMP is guided by eight program objectives used to determine technical direction and activity. The objectives are:

1. Build and sustain relationships with multi-disciplinary partners to expand road weather management (RWM) deployments.
2. Ensure road weather management investments improve highway performance.

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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.

3 Federal Highway Administration, 2015 Road Weather Management Performance Measures Survey, Analysis, and Report. FHWA-HOP-16-001, January 2016. Available at: https://ops.fhwa.dot.gov/publications/fhwahop16001/fhwahop16001.pdf.

3. Advance the 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 the engagement of the operations community with climate change and sustainability communities.

To support these objectives, the RWMP has produced several research products and services. Some of the most recent products include:

- ***Road Weather Management Capability Maturity Framework (RWM CMF).*** The RWM CMF includes a model and electronic tool that is publicly available to transportation agencies to help them assess their current strengths and weaknesses and develop a targeted action plan for road weather management within their individual agencies and regions.
- ***Every Day Counts (EDC) Initiative – Weather Savvy Roads.*** The Weather Savvy Roads innovation consists of two road weather management solutions: (1) Pathfinder and (2) Integrated Mobile Observations (IMO). Implementing these innovations will help agencies better manage their road network and inform travelers before and during adverse road weather conditions.
- ***Weather Responsive Traffic Management (WRTM) Implementation Projects.*** The program worked with three State departments of transportation (DOT) to evaluate the use of mobile road weather data to improve road weather management.
    1. Wyoming DOT Road Condition Reporting Application.
    2. South Dakota DOT Regional Traveler Information System.
    3. Michigan DOT Weather-Responsive Traveler Information System.
- ***Benefit-Cost Analysis for Road Weather Management.*** The RWMP continued to expand the application of benefit-cost analysis (BCA) for RWM through the development of technical briefs (three were published in last 2 years). The briefs, which complement the RWM BCA Compendium of Case Studies, serve as resources for agencies to understand and apply BCA on their agency RWM practices. The RWM BCA Compendium was also recently updated to include additional case studies, increasing the total number of case studies/examples in the document to 27.

- ***Road Weather Connected Vehicle (CV) Applications Program.*** Several activities are underway for this program including: (1) development and implementation of guidelines for deploying connected vehicle-enabled WRTM; (2) support for the Wyoming CV deployment pilot which includes a strong weather component; and (3) development and demonstration of an Integrated Model for Road Condition Prediction (IMRCP).
- ***Weather Data Environment.*** The Weather Data Environment (WDE) is a research project that collects and shares transportation-related weather data with a particular focus on weather data related to CV applications. The WDE collects data in real time from both fixed environmental sensor stations and mobile sources. Since the past update, continued development of the WDE has primarily been to support the stability of the system and maintain State DOT Road Weather Information Systems (RWIS) station information changes.

APPROACH

The research team's approach for the 2017 update included a review of 2015 RWMP performance measures and results, as well as the program's current objectives, activities, and products. The team then developed a plan for conducting the 2017 update and provided recommendations for presenting the results. In general, the reporting period for the performance update is from 2015 to mid-year 2017. The four categories of sources that provided data elements for the performance measures are listed:

- ***RWMP Records.*** The FHWA RWMP's research, training, and stakeholder engagement activities are documented in its records. These data represent the location and extent of the RWMP activities.
- ***State DOT Survey.*** A targeted survey of State DOTs provided data on the current practices and capabilities for RWM around the country. The survey was completed by 40 State DOTs (an 82 percent response rate), which is the same number of States that responded to the 2015 survey, facilitating quantitative comparisons. Figure 1 (shown on the following page) illustrates the distribution of the survey respondents.
- ***Agency Sources, Literature Reviews, and Internet Searches.*** Road weather data from other Federal, State, and local agency sources, along with research institutions (e.g., databases, literature reviews, case studies, publications) provide additional inputs into the performance measure update—especially information pertaining to system outcomes and specific case studies or evaluations 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. In many cases, these data elements are used to support the findings for the performance measures.

Source: Leidos

Figure 1. Map. State department of transportation survey respondents.

For this update, the team explored an alternative approach to presenting the performance measure results and mapped the 27 performance measures into at least one of the following categories:

1. Road weather management impacts.
2. Application of road weather management tools and technologies.
3. Road weather management capacity building.
4. Partnerships and stakeholder collaboration.

Mapping the performance measures to the appropriate category (or categories) allows the RWMP to tell a simple and concise story regarding the performance measure results instead of merely presenting each metric's latest results. These categories allow a big picture assessment of the RWMP's progress and success. Presentation and analysis of individual performance measures are presented in Appendix B.

Table 1. Performance measure mapping.

Performance Measure	RWM Impacts Assessment	Application of RWM Tools and Technologies	RWM Capacity Building	Partnerships & Stakeholder Collaboration
1. Number of agencies participating in road weather research and development projects.			X	X
2. Number of agencies participating in and benefiting from RWM stakeholder meetings/ workshops.			X	X
3. Number of agencies that collect and report road weather-related performance measures to the public.	X			
4. Number of agencies that have a process for evaluating the RoI or net benefit of their RWM investments.	X		X	
5. Reductions in agency costs of weather-related maintenance and operations activities.	X			
6. Reduction in number and types of fatalities and crashes attributed to adverse weather nationally.	X			
7. Reductions in extent of capacity losses and delays due to fog, snow, and ice events including freight.	X			
8. Increase in travel time reliability or decrease in variability due to RWM strategies during adverse weather scenarios.	X			
9. Reduction in number of tons of salt or chemical usage in U.S. normalized by winter severity index.	X			

Table 1. Performance measure mapping (continued).

Performance Measure	RWM Impacts Assessment	Application of RWM Tools and Technologies	RWM Capacity Building	Partnerships & Stakeholder Collaboration
10. Number of State DOTs participating in Meteorological Assimilation Data Ingest System (MADIS) program.		X		X
11. Number of State DOTs that subscribe to RW products and services.		X		
12. Number of State DOTs collecting mobile observations of road weather data from vehicle fleets.		X		
13. Number of State DOTs reporting the use of ESS in operations and maintenance activities.		X		
14. Number of/percentage of responding agencies using mobile data-based applications in RWM.		X		
15. Number of States disseminating advisory weather and RW information to travelers.			X	
16. Number of agencies using control and treatment strategies during weather events.			X	
17. Number of agencies participated in or conducted RWM capability maturity assessment exercises.			X	
18. Number of agencies that coordinate with their local forecast offices for RWM and operations.			X	
19. Number of agencies adopting maintenance decision support systems (MDSS) technology and methods.		X		

Table 1. Performance measure mapping (continued).

Performance Measure	RWM Impacts Assessment	Application of RWM Tools and Technologies	RWM Capacity Building	Partnerships & Stakeholder Collaboration
20. Number of agencies using other weather-related decision-support tools.		X		
21. Number of agencies reporting use of analysis tools to factor weather imp acts and strategies.		X		
22. Number of agencies and attendees who have taken sponsored RWMP training courses and workshops.			X	
23. Number of agencies and participants in RWM webinars led by the RWMP.			X	X
24. Number of meetings, site visits or venues where RWM presentations/ briefings were made.			X	X
25. Number of hits/visits to RWMP websites.*				X
26. Number of public agencies meeting Infrastructure Voluntary Evaluation Sustainability Tool (INVEST) and/or sustainability criteria related to RWM.		X	X	
27. Number of agencies conducting vulnerability/risk assessment or developing/ implementing resiliency plans, for their RWM infrastructure and processes to respond to climate change and extreme weather.		X	X	

* No new data was available for Performance Measure 25, Number of hits/visits to RWMP websites.

DOT = department of transportation. ESS = environmental sensor station. ROI = return on investment. RWM = road weather management. RWMP = Road Weather Management Program.

ORGANIZATION OF REPORT

The remainder of the report is organized such that each chapter is able to stand alone. As mentioned, the research team mapped each performance measure to one or more of the four categories. For example, if the reader would like to learn more about the extent the RWMP has been partnering or collaborating with various stakeholders, Chapter 5 will provide that story using a combination of performance measure results.

- ***Chapter 2, Road Weather Management Impacts,*** describes the recent findings related to mitigating the mobility, safety, productivity/economic and environmental impacts of adverse weather conditions.
- ***Chapter 3, Application of Road Weather Management Tools and Technologies,*** examines the specific road weather tools and technologies and the extent to which State agencies have applied them.
- ***Chapter 4, Road Weather Management Capacity Building,*** shows how the RWMP is providing stakeholders with flexible and accessible learning and growth opportunities through training, technical assistance, and resources.
- ***Chapter 5, Partnerships and Stakeholder Collaboration,*** describes how the RWMP is collaborating and partnering with public and private stakeholders through various activities.
- ***Chapter 6, Recommendations and Conclusions,*** presents overall conclusions from the 2017 update and recommendations for the RWMP and its next performance measure update effort.

This report also includes two appendices, which provide the following information:

- Appendix A lists the State DOT survey questions and response summary.
- Appendix B presents the findings for each performance measure.

Chapter 2. Road Weather Management Impacts Assessment

OVERVIEW

Meaningful improvements in highway performance during adverse weather conditions are expected to be realized as a result of increased nationwide implementation of various road weather management (RWM) strategies. The Federal Highway Administration (FHWA) Road Weather Management Program (RWMP) uses a handful of performance measures (discussed in the following Performance Findings section) to monitor the recent progress on road systems across the country, particularly as it relates to mitigating the negative impacts of adverse road weather conditions. The pathways from program activity to overall macro-level outcomes are complex, and direct correlation between a specific RWMP program activity and road weather impacts is not possible. However, overall trends provide a snapshot into the scope of the problem agencies face today, as well as some practices that have shown positive benefits.

PERFORMANCE FINDINGS

Collecting and Reporting Performance Measures

State departments of transportation (DOTs) have demonstrated an enhanced level of awareness of and interest in understanding the performance of their systems and the outcomes associated with their road weather management response. However, State DOTs are still figuring out how best to collect and report this metric. Information from the State DOT survey was used to determine how many State transportation agencies currently collect road weather performance data (e.g., dashboards, winter maintenance reports, seasonal summaries) and report it to the public. Among the 40 State DOTs that responded to the survey, 22 of them (56 percent) reported regularly collecting and reporting some form of road weather performance measures, while 4 respondents were uncertain. The number of "yes" responses in the 2017 survey decreased slightly from the 2015 level (58 percent), as seen in Figure 2 below.

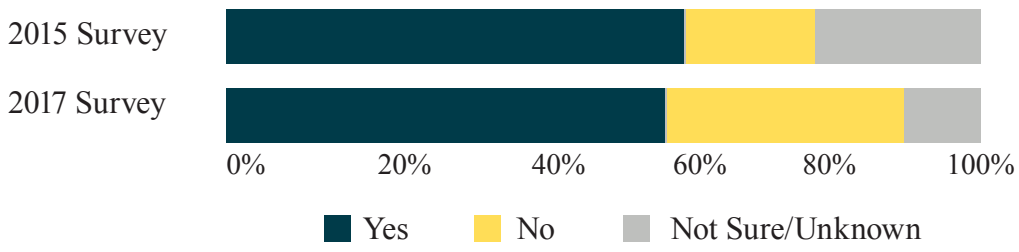

Figure 2. Chart. Percentage of agencies that collect and report road weather performance measures.

While the reported number of agencies collecting RWM performance data in 2017 is slightly lower than it was in 2015, it is interesting to note that the "Not Sure/Unknown" responses were cut in half. Nevertheless, it is important that more than 50 percent of the responding States have begun considering the collection of road weather performance data. Continued development of a consistent set of measures in the future is critical to enabling assessment of impacts across the Nation.

The 2017 survey also found that 41 percent of State DOTs (18 out of 40) use a "winter severity index" to compare performance across events or across years. This metric was not collected in the last iteration of this report, so this presents a new area of potential improvement to measure in the coming years.

As seen in Figure 3, nine States reported having a process in place to evaluate return on investment or the net benefits of road weather management investments; this is almost twice the number of States that had such a process in 2015 (five States). A 2014 Transportation Research Board research paper[4] compared winter crash data on roadway segments in Idaho before and after deployment of Road Weather Information Systems (RWIS) sites and calculated a benefit-cost ratio of 22, easily justifying the investment. As more States begin implementing such metrics and using the tools and resources that have been developed by FHWA RWMP for conducting benefit-cost analyses (BCA) on RWM activities, a stronger case can be made to further widen the breadth of RWM strategy deployment across the country.

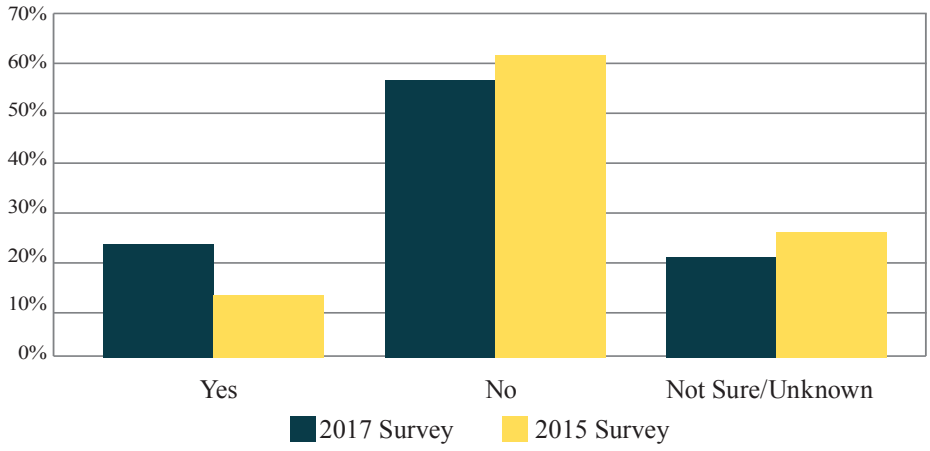

Figure 3. Chart. Performance measure 4 – percentage of agencies surveyed with a process for evaluating the return on investment or net benefit of their road weather management investments.

4 Koeberlein, R., Jenson, D., and Forcier, M., "Relationship of Winter Road Weather Monitoring to Winter Driving Crash Statistics," Transportation Research Board, October 24, 2014.

National Trends in Road Weather Impacts

The research team used additional performance measures to assess the economic impacts that States are facing every year – namely, winter maintenance costs (snow and ice removal, salt usage) – due to adverse road weather conditions.

Figure 4 summarizes data from the latest iteration of FHWA Highway Statistics detailing national expenditures for snow and ice removal (in thousands of dollars) between 2001 and 2013:

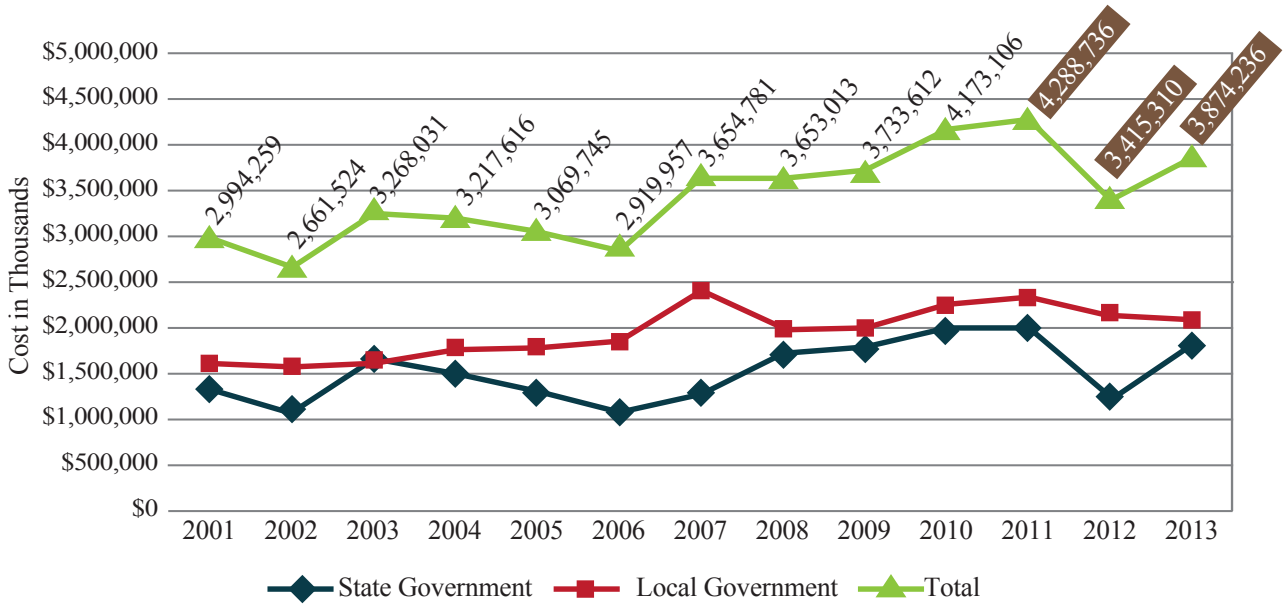

Figure 4. Graph. National expenditures for snow and ice removal, 2001-2013.

While local governments have seen a reduction in expenditures for snow and ice removal between 2012 and 2013 (the latest period of data available), State government expenditures have risen in the corresponding time period – resulting in a total expenditure increase of about 13 percent. This slight increase in expenditure is a shift in direction from the previous decline between 2011 and 2012.

The above observations in large part are attributed to the natural, unpredictable variation in weather and road weather conditions in the short run. Virginia and Pennsylvania experienced the largest increases between 2012 and 2013, spending an additional $80 million and $92 million on winter operations and maintenance, respectively. However, specific examples such as a 2016 case study in Idaho[5] demonstrated that equipping electronic spreader control systems on snowplow trucks and installing RWIS sites throughout the State helped lower the State's winter maintenance costs by 29 percent over three years; in fact, between 2013 and 2014, Idaho's winter maintenance expenditures were reduced by nearly $2 million.

5 Idaho Transportation Department, The Transporter, "ITD sees drop in accidents on icy roads thanks to electronic spreader control system," January 8, 2016. Available at: http://apps.itd.idaho.gov/apps/MediaManagerMVC/transporter/2016/010816_Trans/010815_ITDIcyRoads.html

An assessment of the overall expenditures between 2001 and 2013 reveals no noteworthy trend in the data. While some States are implementing innovative solutions to reduce road weather maintenance costs, the long-term nationwide expenditures have slightly risen. This variability and the lack of a trend can also be seen in Figure 5, which summarizes the latest data on nationwide salt usage (2006-2014) from the United States Geological Survey (USGS).

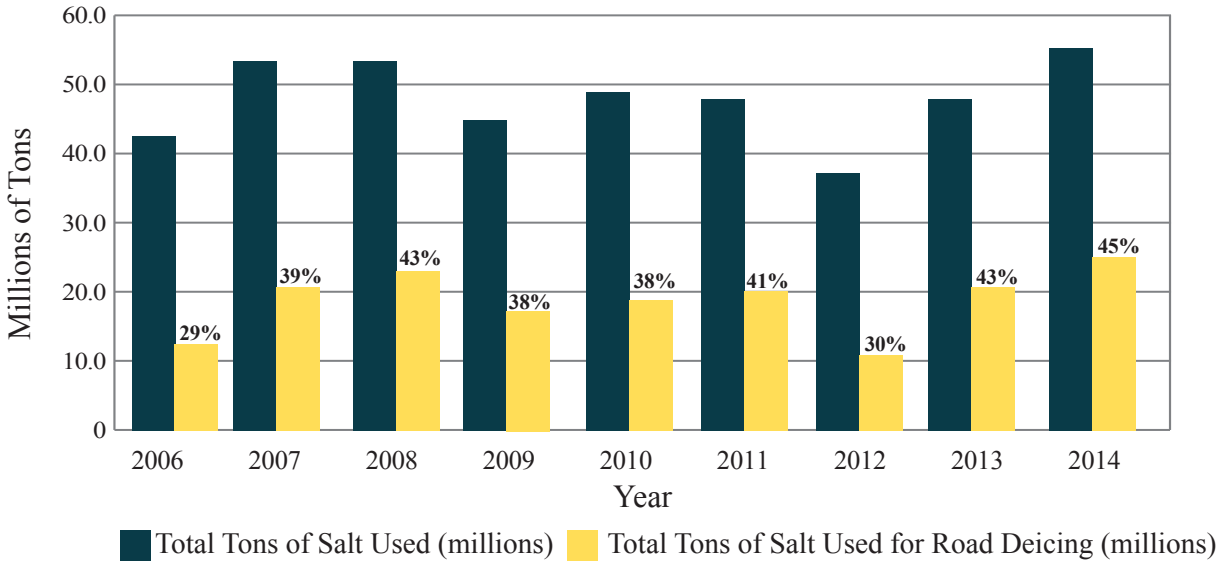

Figure 5. Graph. Nationwide salt usage, 2006-2014.

While there was a 20 percent increase in the amount of salt used for de-icing between 2013 and 2014, the overall trend fluctuates often. Nevertheless, a few States have demonstrated notable, promising case studies of how nationwide salt usage can still be better controlled as a result of innovative RWM strategies:

- Iowa reported that since the State began using a Salt Dashboard, the amount of salt used statewide has been "consistently and often significantly" below the target. This has contributed to savings of more than $2.7 million annually since 2012.[6]
- Maryland has reduced its salt usage by 40 percent over the past three winters through its Statewide Salt Management Plan.[7]
- Peel, California Public Works has implemented Salt Management Plan to reduce salt usage which includes: use of road weather information systems to give advanced forecasting to ensure the best application technique is used, improved salt storage and handling, and better route planning.[8]

6 "Iowa's Salt Dashboard Helps Garages Use Salt Efficiently," Clear Roads Newsletter, August 2016. Available at: http://clearroads.org/august-2016/.

7 Basch, M., "Road crews cut back on salt in Maryland," *WTOP*, December 15, 2016. Available at: http://wtop.com/weather-news/2016/12/road-crews-cut-back-salt-maryland/.

8 Region of Peel-Public Works-Transportation-For Residents-Other Salt Reducing Initiatives website. Accessed September 11, 2017. Available at: https://www.peelregion.ca/pw/transportation/residents/salt-reduction.htm

Roughly half of the 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, contributing to 15 percent of this type of delay.[9] This is estimated to result in an annual delay of 544 million vehicle-hours across the country.[10] In addition, snow accumulation, precipitation (type, rate, and start/end times), extreme wind speeds, and water levels also lead to a decrease in highway capacity. Directly reducing the delays experienced by travelers driving in inclement weather conditions, therefore, is one of the key elements of system performance improvement targeted by RWMP. Since the last performance measure update, two additional noteworthy delay-reducing strategies were identified.

- Michigan's weather responsive traveler information system, Wx-TINFO. After implementing this strategy, user delay costs decreased statewide between 25 and 67 percent during National Weather System advisory and warning alert periods.[11]
- Utah's PathFinder Team. This strategy involved collaboration between the Utah Department of Transportation; WeatherNet, LLC.; Weather Forecast Offices in Salt Lake City, Utah, and Grand Junction, Colorado; and the University of Utah. A survey was completed after one weather event. Results revealed that 62 percent of survey respondents changed their schedule, 26 percent changed their route, and 13 percent decided not to travel.[12]

Finally, an assessment of RWM impacts would not be complete without considering safety impacts of managing adverse weather – in this case, the reduction in number and types of fatalities and crashes on the road. On average, there are over 5,870,000 vehicle crashes (resulting in injuries or fatalities) annually, 23 percent of which are attributed to adverse weather and its effect on visibility and road surface conditions.[13] As listed in Table 1, Performance Measure 6 tracks the reduction in nationwide numbers and types of fatalities attributed to adverse weather. Databases like the Fatality Analysis Report System, National Highway Traffic Safety Administration's (NHTSA) National Automotive Sampling System General Estimates System, and NHTSA's National Motor Vehicle Crash Causation Survey provide national-level summaries, seen in Figures 6 and 7.

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9 USDOT, FHWA, Office of Operations Road Weather Management Program, "Operations Story." Accessed September 11, 2017. Available at: http://ops.fhwa.dot.gov/aboutus/opstory.htm.

10 USDOT, FHWA, Office of Operations Road Weather Management Program, "How do Weather Events Impact Roads?" Accessed September 11, 2017. Available at: http://ops.fhwa.dot.gov/weather/q1_roadimpact.htm.

11 USDOT, FHWA, Road Weather Management Program, "Michigan Department of Transportation (MDOT) Weather Responsive Traveler Information (Wx-TINFO) System," FHWA-JPO-16-324, January 2016. Available at: https://ntl.bts.gov/lib/57000/57000/57050/FHWA-JPO-16-324_v1_-_MDOT_Flyer.pdf.

12 USDOT, FHWA, Office of Operations, "Collaboration Across the Road Weather Enterprise: The Pathfinder Project," FHWA-HOP-16-086, December 2016. Available at: https://ops.fhwa.dot.gov/publications/fhwahop16086/index.htm#toc.

13 USDOT, FHWA, Office of Operations Road Weather Management Program, "How do Weather Events Impact Roads?" Accessed September 11, 2017. Available at: http://www.ops.fhwa.dot.gov/weather/q1_roadimpact.htm.

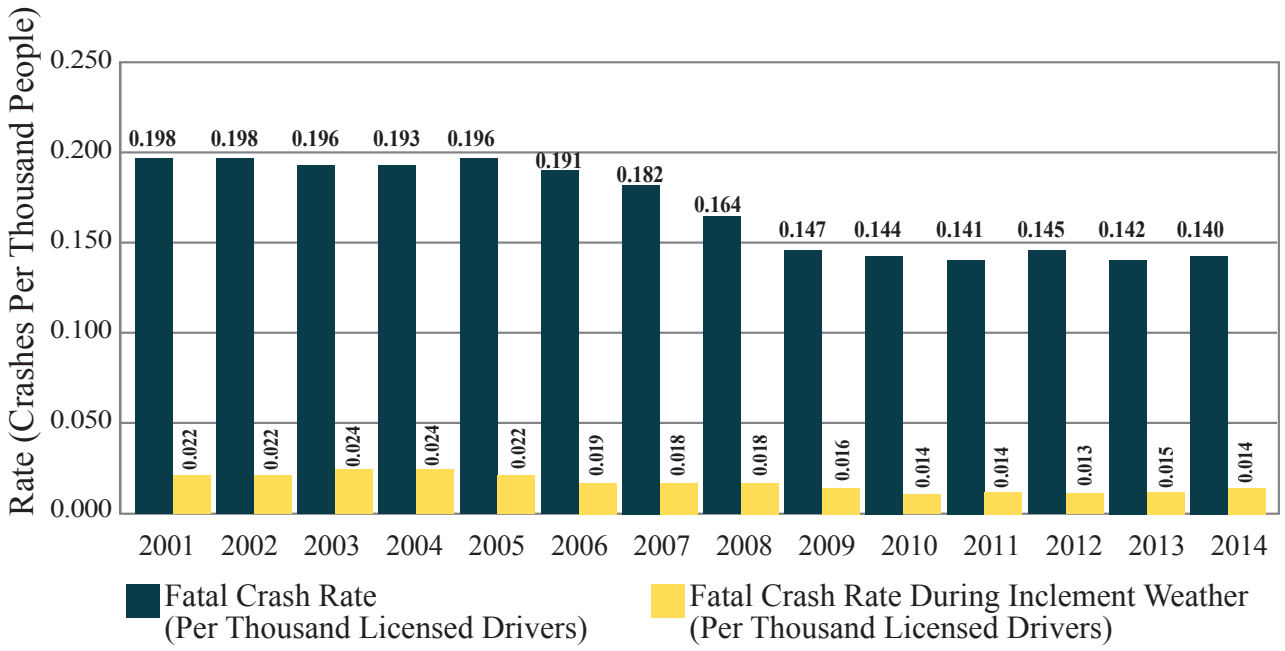


Figure 6. Graph. Fatal crash rates per thousand licensed drivers, 2001-2014.

The 2014 data is the newest addition since the last iteration of this report. The number of fatal crashes during inclement weather in 2014 was 3,094—very similar to the 2013 number (3,157). However, since the total number of drivers on the road increased by nearly 2 million, this resulted in a slight decrease in the fatal crash rate during inclement weather (per thousand drivers).

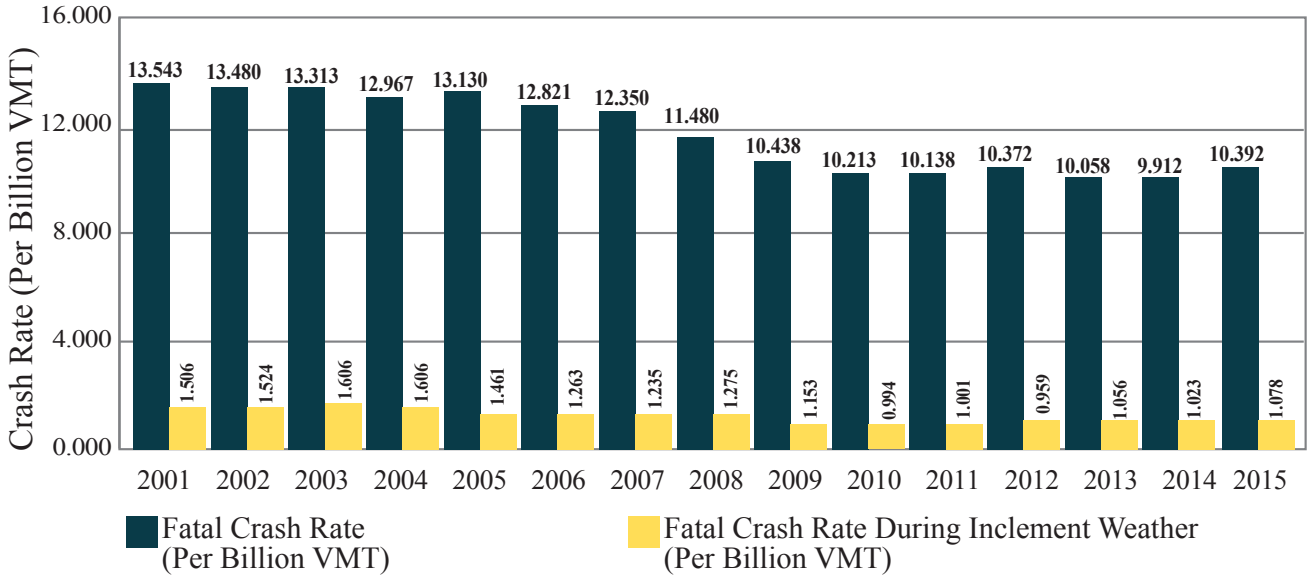


Figure 7. Graph. Fatal crash rates per billion vehicle miles traveled, 2001-2015.

Viewed from the perspective of vehicle miles traveled (VMT), it is clear that fatal crash rates follow a similar trend. Both figures illustrate how the crash rates decreased since 2001; however, the last six reported years have leveled out. While there is a decrease in both the overall and the inclement weather crash rates, the weather crash rate is decreasing at a slower rate than the overall crash rate.

Statistics show that the vast majority of weather-related crashes occur on wet pavement and during rainfall:[14]

- Seventy-three percent occur on wet pavement.
- Forty-six percent happen during rainfall.
- Seventeen percent ensue during snow/sleet.
- Thirteen percent occur on icy pavement.
- Fourteen percent take place on snowy/slushy pavement.
- Three percent transpire during foggy conditions.

The fact that the percentage of fatal crashes occurring during inclement weather held fairly steady at an average of 11 percent between 2001 and 2015 (without swaying more than 2 percent in either direction) suggests that the decrease in fatal crashes during adverse weather is most likely a result of decreasing crash rates overall—regardless of the weather condition. There is not enough evidence to suggest that weather-related fatal crashes decreased independently as a result of RWM-specific strategies.

14 U.S. DOT FHWA Office of Operations Road Weather Management Program, "How do Weather Events Impact Roads?" Accessed August 24, 2017. Available at: http://www.ops.fhwa.dot.gov/weather/q1_roadimpact.htm.

Chapter 3. Application of Road Weather Management Tools and Technologies

OVERVIEW

The previous chapter offered insights into the impacts on transportation system performance (particularly highways) that States have experienced as a result of implementing road weather management (RWM) strategies. This section focuses on the specific tools and technologies used by agencies for road weather management, including the number of State departments of transportation (DOT) that have adopted them to date.

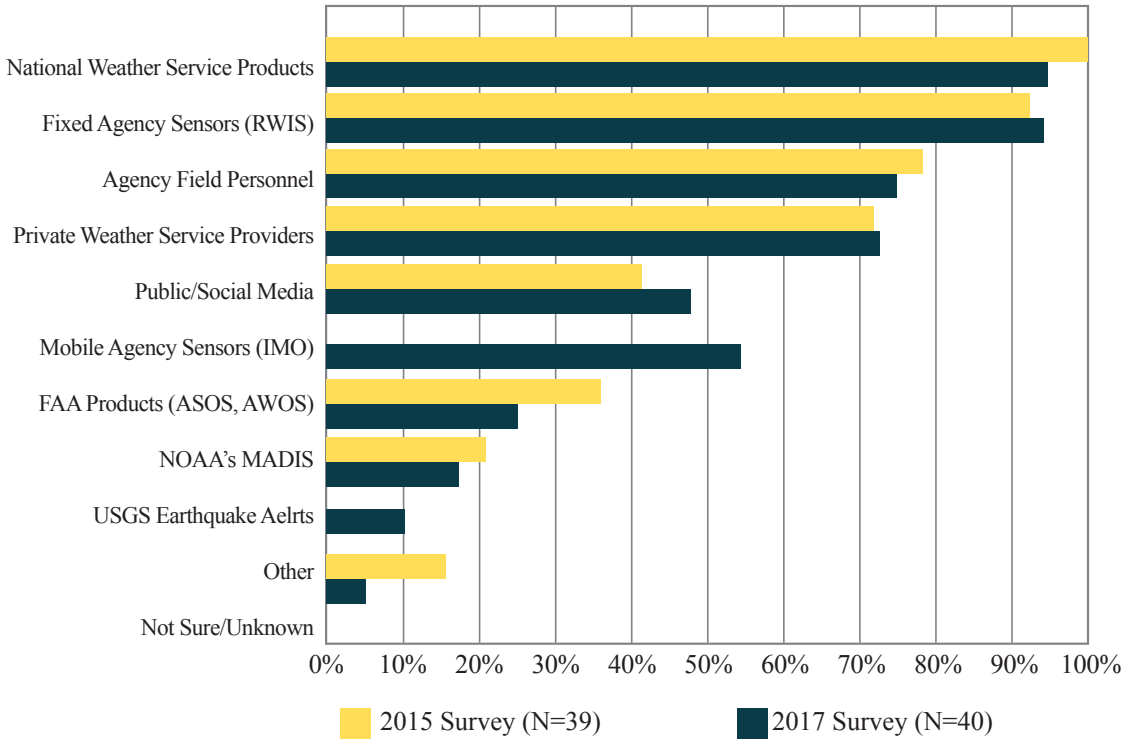
PERFORMANCE FINDINGS

Use of Fixed and Mobile Observations

The first set of RWM tools pertains to the collection of fixed and mobile road weather observations, which can take the form of real-time or archived road weather data. The objective is not only to examine the availability of such data but also to review the subscription rates and use of observational data among State DOTs—which gauge the impact of the availability of data on strategic and tactical decision making for weather-related maintenance and traffic operations. The overall success of this objective has been assessed by four performance measures, which track the number of State agencies that use these types of road weather data collection systems and strategies. The number of State DOTs using such systems since the previous report has decreased for a few tools but increased for the majority of tools assessed, suggesting an overall slight improvement in this objective.

The number of State DOTs participating in the National Oceanic and Atmospheric Administration's Meteorological Assimilation Data Ingest System (MADIS) Program has increased. MADIS is a system that offers a robust set of quality-checked data that is available to support traffic management, inform maintenance-related decision making and performance measurement, and provide information on current conditions to the traveling public at a national level. Since 2016, 10 more States have contributed data to MADIS, bringing the total number of participants to 21. These States are Delaware, Florida, Georgia, Kansas, Massachusetts, Nevada, New Jersey, Ohio, South Dakota, and Wisconsin.

State DOTs reported high levels of subscription to weather and road-weather products and services that support the DOTs' 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 National Weather Service (NWS), the Federal Aviation Administration, sensors deployed by Federal and State agencies, and private sector value-added services. Since 2015, the number of subscribers of these services has remained relatively constant, with some products and services seeing increases in popularity while other have seen declines as shown in Figure 8.



ASOS = Automated Surface Observing System. AWOS = Automated Weather Observation System. IMO = Integrated Mobile Observations. FAA = Federal Aviation Administration. MADIS = Meteorological Assimilation Data Ingest System. NOAA = National Oceanic and Atmospheric Administration. RWIS = Road Weather Information System. USGS = United States Geological Survey.

Figure 8. Chart. Percentage of States that subscribe to weather and road weather products and services.

Survey data reflect a notable growth in the collection and use of mobile road weather data from vehicle fleets since the last update (see Figure 9). In addition to vehicle location data from automatic vehicle location systems and radio communication between the driver and the maintenance center, mobile road weather observations can 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.

Overall, 23 of the 40 States that responded to the survey, more than 50 percent, collect real-time field data from maintenance vehicles. This is an increase from 20 States in the 2015 survey. Collecting plow status and material usage is most common, with 13 States reporting that they collect more than 50 percent of their data from maintenance vehicles. Compared to the 2015 survey, there was an overall increase in the number of States that collect at least 25 percent of their real-time field data on plow status and material usage, atmospheric weather data (e.g., air temperature, relative humidity), and road weather conditions data (e.g., pavement temperature). This growth is expected to continue with ongoing Road Weather Management Program (RWMP) efforts to implement Integrated Mobile Observations (IMO) as part of the Weather Savvy Roads Initiative.

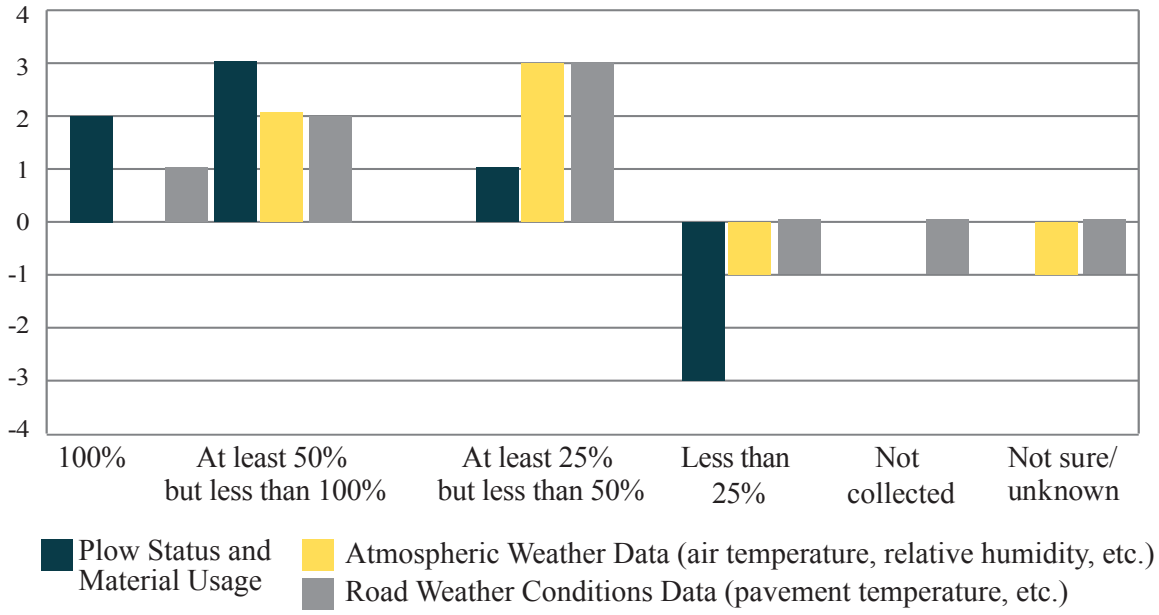
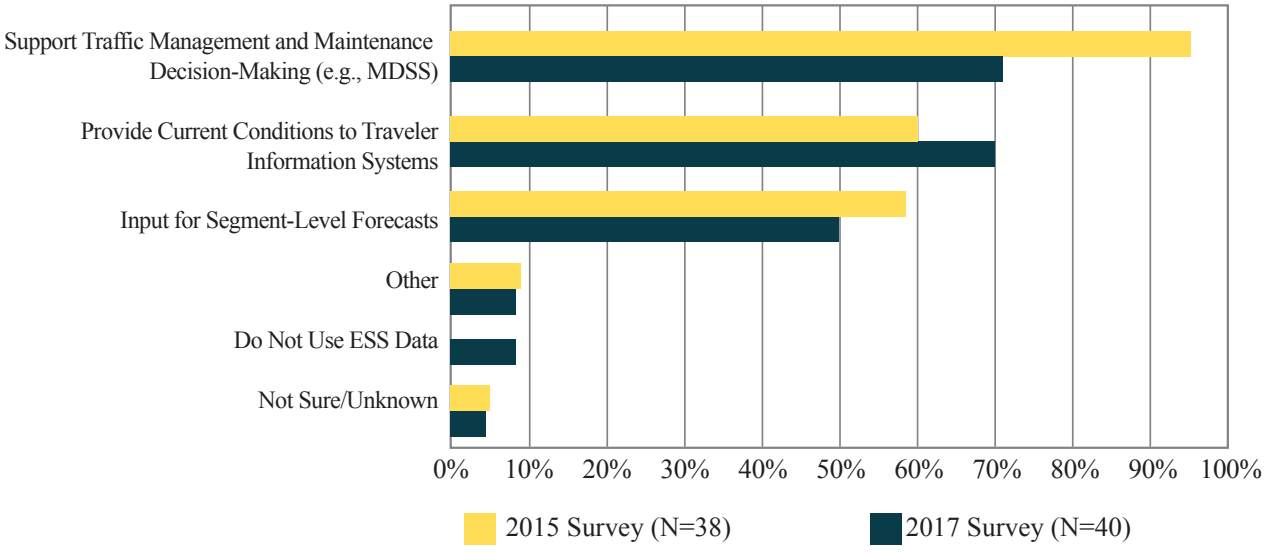


Figure 9. Chart. Change in the number of State departments of transportation collecting data from maintenance vehicles and percentage of applicable fleets from which data are collected (from 2015 survey).

Finally, from the State DOT survey, the respondents reported managing a total of 2,464 environmental sensor stations (ESS), which continues the slight decrease seen in the previous update. The majority of respondents use ESS data to provide current conditions to traveler information systems, to support decision making, and as input to segment-level forecasts. However, while 70 percent of State DOTs use ESS data for traveler information systems, only 73 percent report using this data for decision making, which is down from 95 percent in the previous period. A positive change can be seen in the increase in the percentage of State DOTs that use ESS data to provide current road conditions to traveler information systems – from 60 percent in the 2015 survey to 70 percent in the 2017 survey.



ESS = Environmental Sensor Station. MDSS = Maintenance Decision Support System.

Figure 10. Chart. Use of environmental sensor stations among State departments of transportation.

Use of Vehicle-to-Infrastructure or Infrastructure-to-Vehicle Applications and Connected Vehicle Technology

Still in its infancy, State DOTs are in early stages of connected vehicle deployments. Survey results reveal that only 17 percent of agencies said that they have developed applications or tools that leverage infrastructure-to-vehicle (I2V) or vehicle-to-infrastructure (V2I) connectivity:

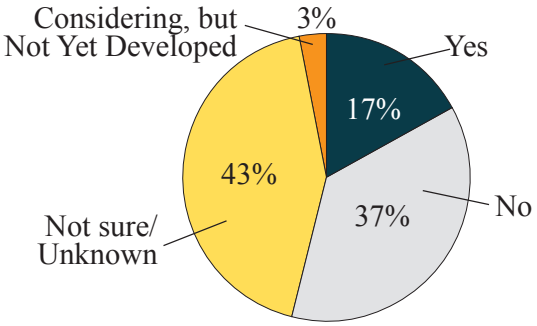
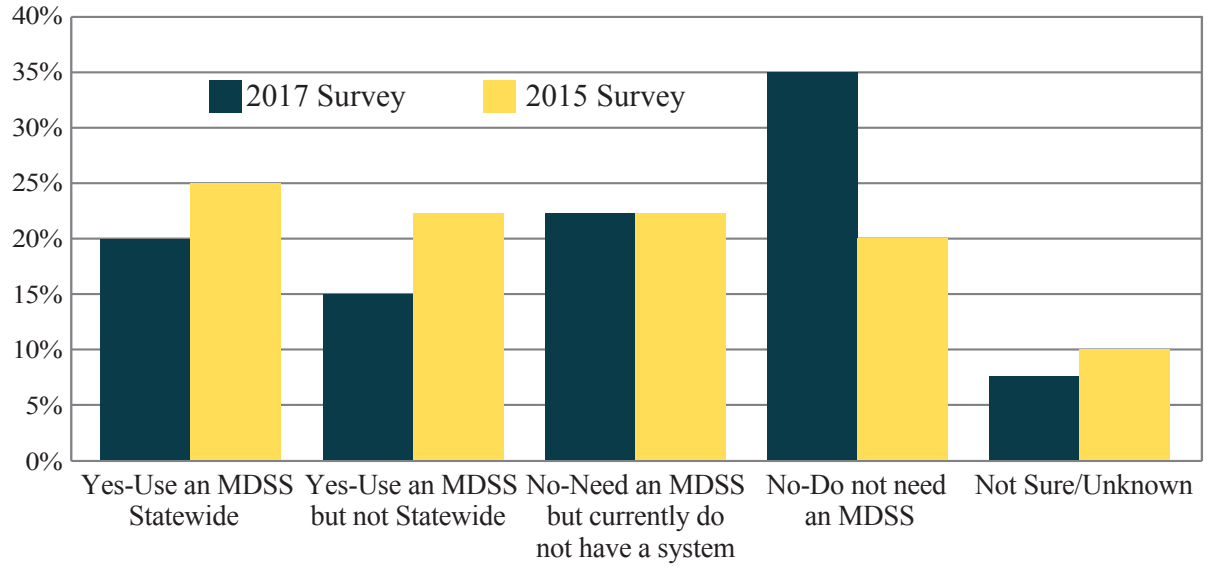


Figure 11. Chart. Performance Measure 14 – survey responses on the use of vehicle-to-infrastructure or infrastructure-to-vehicle connectivity.

Use of Decision Support Tools

The percentage of State DOTs using Maintenance Decision Support Systems (MDSS), both statewide and partial, has shown a slight decrease; more importantly, there is an increase in the number of States saying that they do not need an MDSS, whereas the percentage of States saying they need it but do not have one has remained steady. While MDSS outreach has not been a focus of the RWMP in the past few years, the need for continued promotion of MDSS benefits appears to be warranted. Use of decision support tools for activities other than winter maintenance has remained steady with traveler information, coordination with other jurisdictions, and non-winter maintenance activities being the top categories of responses and consistent between the 2015 and 2017 surveys. (Refer to Figures 12 and 13.)



MDSS = Maintenance Decision Support System.

Figure 12. Chart. Performance Measure 19 – percentage of State departments of transportation indicating use or non-use of Maintenance Decision Support Systems.

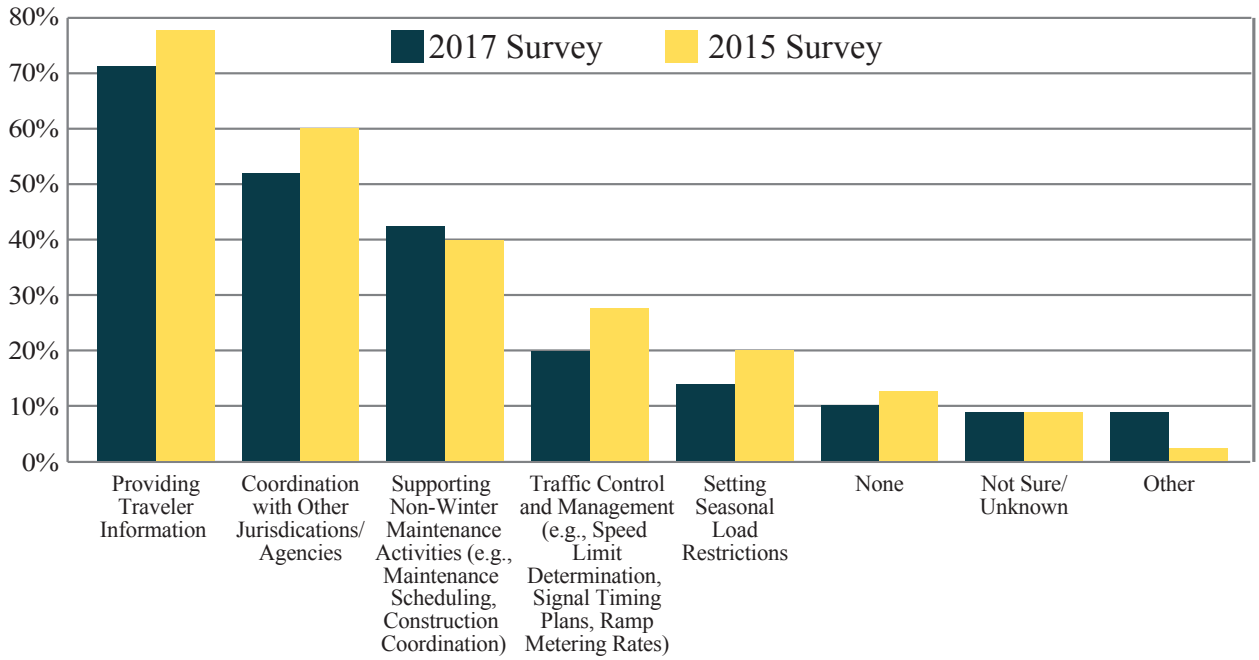
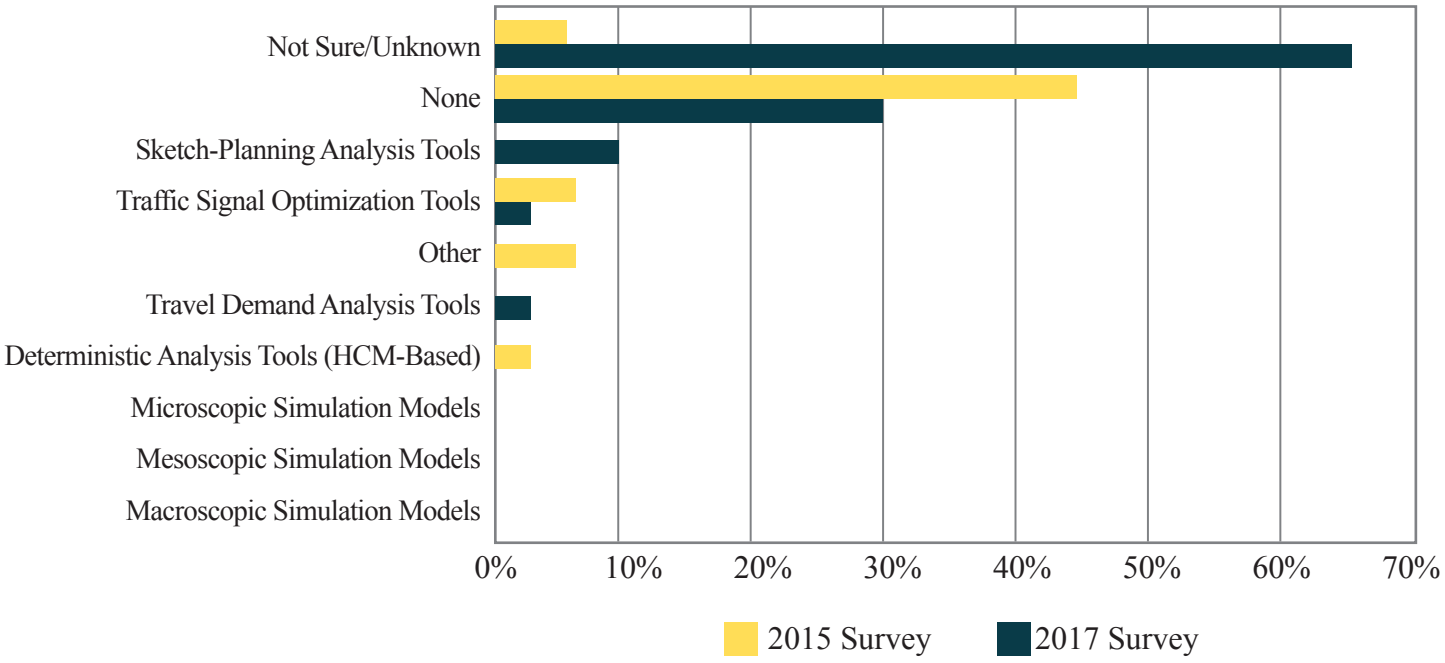


Figure 13. Chart. Performance Measure 20 – percentage of State departments of transportation using weather-related decision support tools for road weather management.



HCM = Highway Capacity Manual.

Figure 14. Chart. Performance Measure 21 – percent of State departments of transportation using weather-responsive traffic analysis and simulation tools for planning and evaluating road weather management strategies.

Ninety-five percent of the State DOT respondents either did not use or were not aware of whether their agency used weather-responsive analysis tools and models. This continues to reflect very low awareness and use of weather-responsive analysis, modeling, and simulation products.

The RWMP continues to support research on weather-responsive analysis, modeling, and simulation tools. These tools provide insight into the operations of new and emerging WRTM strategies and can incorporate the impacts of weather into traffic models. For example, the Chicago Analysis, Modeling, and Simulation testbed provides the ability to model and test several road weather connected vehicle applications and active transportation demand management strategies. In addition, RWMP is piloting the Integrated Modeling of Road Condition Prediction (IMRCP) tool in Kansas City. All these tools provide significant analytical capability, both in a real-time and an offline manner, for understanding the impacts of road weather on traffic volumes and roadway capacity. However, translating them from research to real-world operations remains a challenge due to the complexity in data assembly, calibration, and testing required to make these systems work at a State DOT. Not particular to road weather management alone, the greater use of analytical tools to support reliability is an effort that is being considered more broadly by the Federal Highway Administration (FHWA) Office of Operations as well.

Use of Advisory, Control, and Treatment Strategies for Road Weather Management

No universal approach to developing and implementing strategies to address winter weather exists. A wide range of potential methods and strategies can be tailored to address the unique local conditions. 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.).

When assessing RWM performance from this angle, it is clear that State DOTs are making improvements. Figure 15 shows an increase in the number of agencies (since the 2015 survey) that have deployed road weather information dissemination strategies statewide, such as publicizing atmospheric weather information on dynamic messaging signs, road condition information on dynamic message signs, and road condition information on agency-hosted social media or mobile applications.

In 2016, FHWA's RWMP partnered with the South Dakota DOT to develop and implement a weather responsive traffic management (WRTM) strategy. Twenty-four hour road condition forecasts transfer directly from South Dakota's MDSS to its traveler information systems as possible future "threats" when road conditions might deteriorate due to unsafe situations (Performance Measure 19). Furthermore, in a 2016 Transportation Research Board study, speed and visibility data were analyzed at several locations along I-64 and I-77 in Virginia, where fog often develops. The research aimed to understand motorists' existing speed choices during low visibility conditions. The models revealed that there is a significant differential between observed speeds and the desired safe speed (Performance Measure 21). Hopefully by recognizing more promising case studies like these, more States in the future will be able to integrate weather-related decision support technologies into their traffic operations and maintenance procedures.

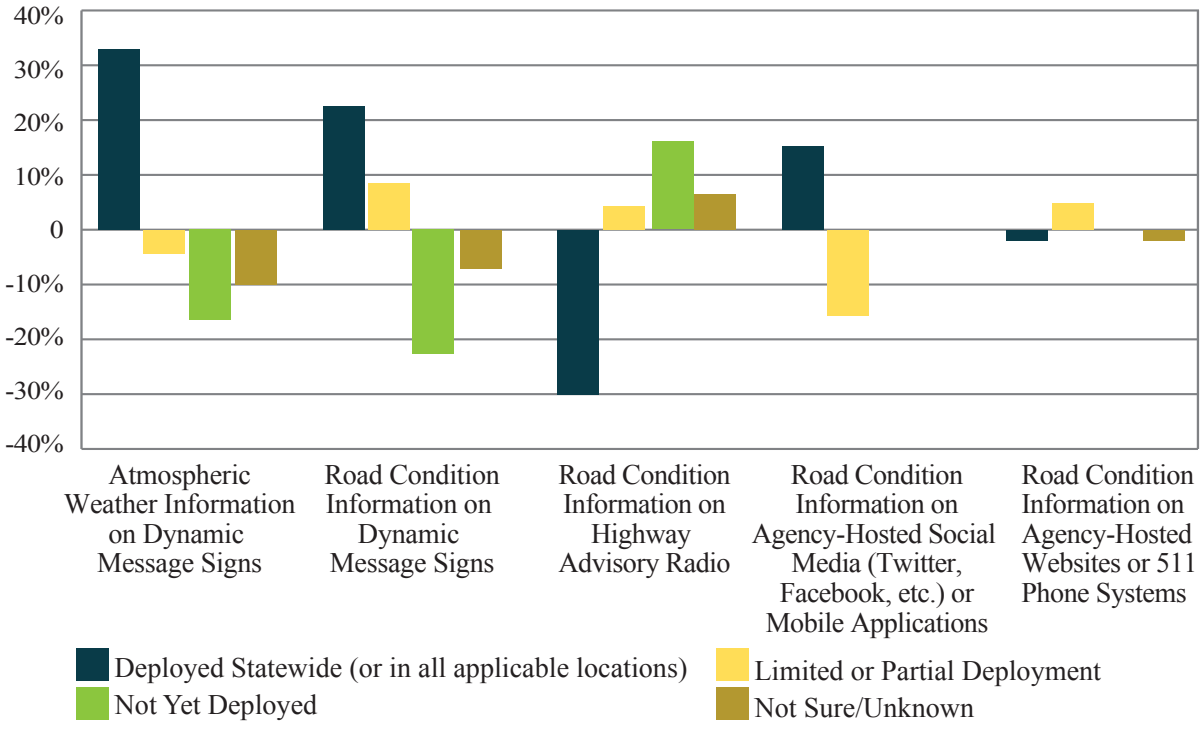


Figure 15. Chart. Performance Measure 15 – number of States disseminating weather advisory and other road weather information to travelers, by type (percentage change from 2015 survey).

The only significant drop in State participation in the above strategies is in the use of highway advisory radio, which is arguably a more outdated means of communications with the public. The more contemporary methods of social media and dynamic message signs, which more easily facilitate real-time, en-route information, have shown significant increases in adoption by State DOTs.

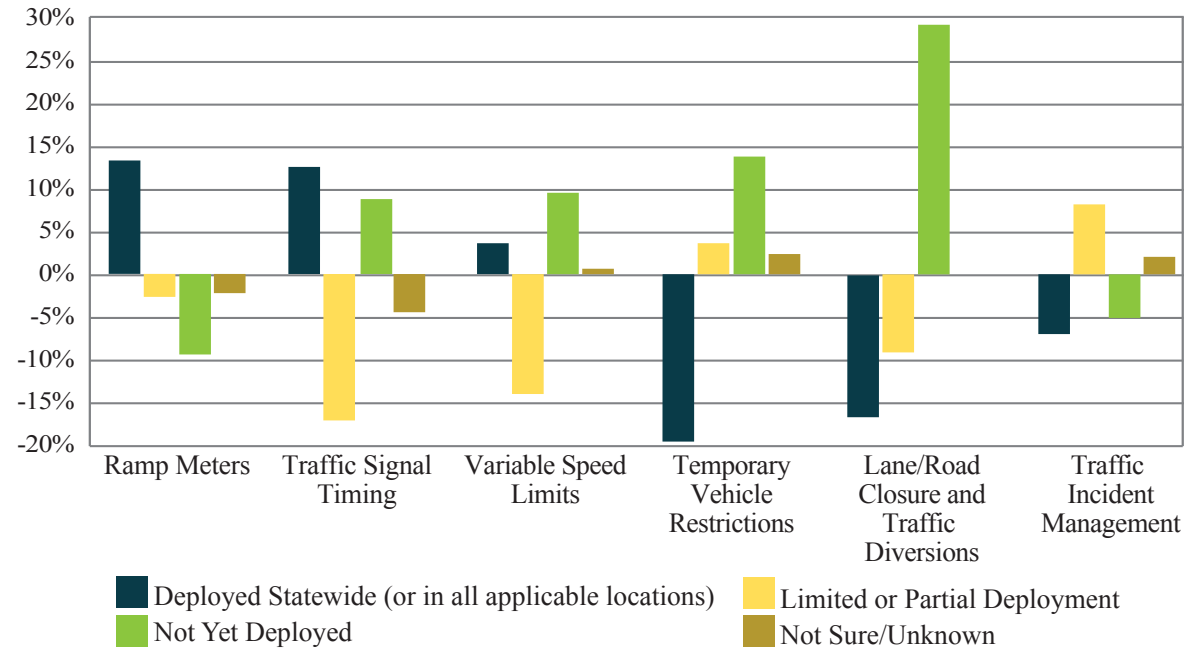


Figure 16. Chart. Performance Measure 16 – deployment levels of control and treatment strategies during weather events (percentage change from 2015 survey).

In the past 2 years, as shown in Figure 16, there was a reported increase in the number of States deploying more automated, innovative traffic control strategies such as ramp meters, traffic signal timing, and variable speed limits. However, ramp metering and signal timing are still at low levels of deployment. This may be an indication that ramp meters, traffic signal timing technologies, and variable speed limits are a good area to focus on relative to road weather management.

Consideration of Extreme Weather and Transportation Resilience and Sustainability

Sustainability for road weather management has largely been restricted to having a snow and ice removal policy. Few agencies have a dedicated road weather management program as shown in Figure 17. The percentage of agencies implementing plans for road weather management infrastructure and developing various processes for managing extreme weather has increased as shown in Figure 18.

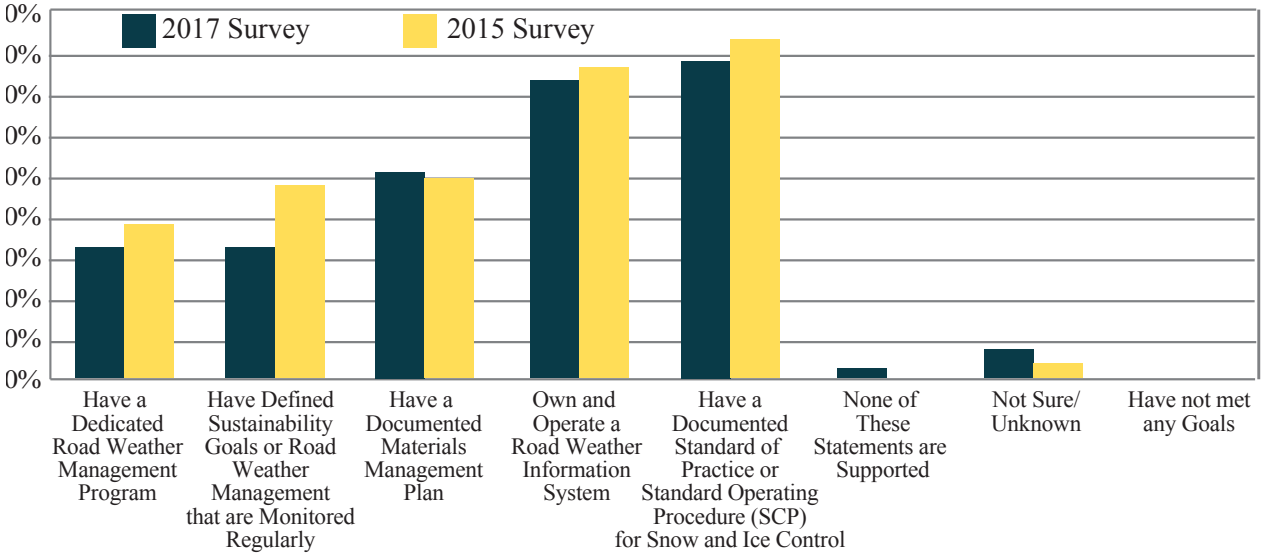


Figure 17. Chart. Performance Measure 26 – percentage of agencies meeting sustainability criteria related to road weather management.

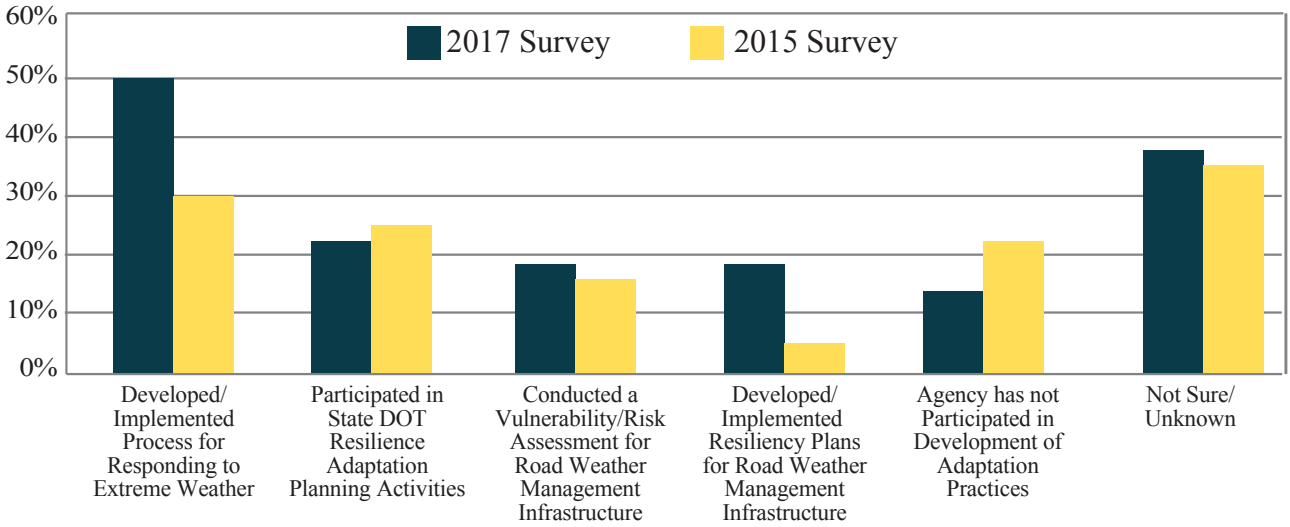


Figure 18. Chart. Performance Measure 27 – percentage of agencies involved in extreme weather or climate change activities.

Chapter 4. Road Weather Management Capacity Building

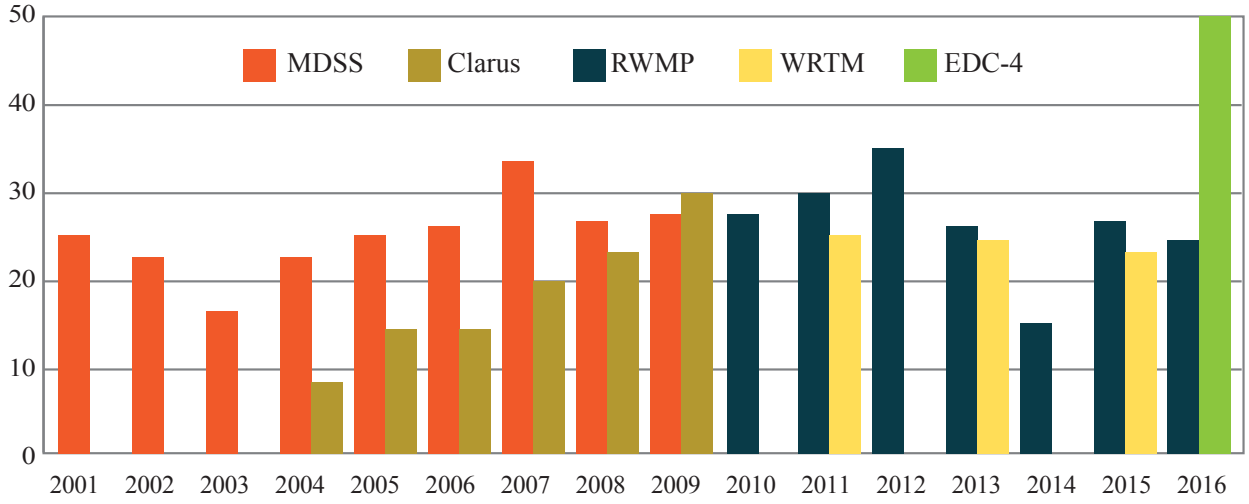
OVERVIEW

Capacity building refers to providing stakeholders with flexible, accessible learning, and growth through training, technical assistance, and educational resources. When applied to road weather management, it includes activities and products that improve the performance of weather-related actions. This includes participation in various stakeholder meetings, road weather research and development (R&D) projects, training programs, conferences, and webinars. The goal of capacity building is to improve individual as well as organizational capacities for addressing and overcoming road weather problems.

PERFORMANCE FINDINGS

Participation in Road Weather Management Meetings and Community of Practice

Participation in road weather management (RWM) meetings has shown a consistent and strong response, as seen in Figure 19. Stakeholder meetings began with a focus on maintenance decision support systems (MDSS) and *Clarus,* but starting in 2010, they shifted to focus more broadly on RWM. Since 2011, stakeholders have met to discuss weather responsive traffic management (WRTM) on a biennial basis.



EDC = Every Day Counts. RWMP = Road Weather Management Program. MDSS = Maintenance Decision Support System. WRTM = Weather Responsive Traffic Management

Figure 19. Graph. States participating in road weather management meetings.

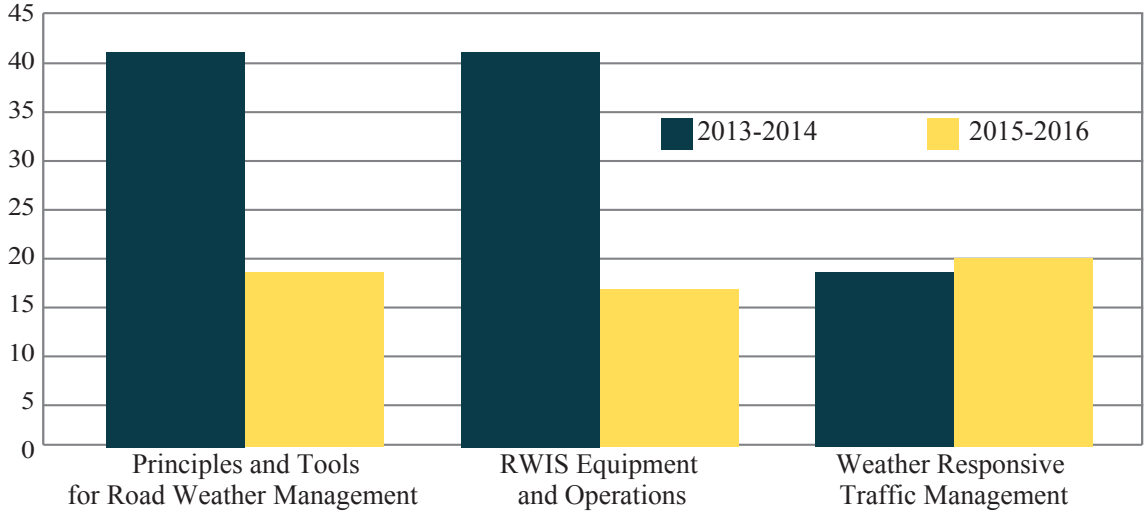
The number of State departments of transportation (DOT) attending the Road Weather Management Program (RWMP) meetings has increased from only 7 in 2014 to about half of the States in 2015 (27) and 2016 (24). The WRTM meeting in 2015 attracted 23 State DOTs. Since 2013, attendance to the WRTM meetings has been limited due to budget restrictions for sponsored travel. The Every Day Counts (EDC) Summits held in 2016 were well-attended, with 48 States participating along with the District of Columbia and the U.S. Virgin Islands. These summits were sponsored by the FHWA Center for Accelerating Innovation to promote the EDC-4 Weather Savvy Roads Initiative.

Participation in Capability Maturity Improvement Workshops

Another important aspect of capacity building is advancing the institutional capabilities for RWM by State DOTs. The Federal Highway Administration's Capability Maturity Framework workshops and tool help agencies to develop action plans for raising existing RWM capabilities based on an evaluation of the agency's current practices, tools, and infrastructure. The Capability Maturity Framework assessment is a first step towards greater mainstreaming of RWM programs at State DOTs. Ten States have already conducted the capability maturity assessment workshops. Since the framework was developed in 2014, there was no participation to report in the previous period. It is encouraging that 10 States, spanning a diverse range of climates, have already participated in the in-person workshops in just a couple of years.

Participation in Road Weather Management Sponsored Training and Webinars

Since 2015, there has been a decline in the number of State agencies participating in courses offered by the Consortium for ITS Training and Education (CITE), as seen in Figure 20. This is expected since the number of RWM practitioners in transportation agencies remains fairly constant. Unless significant hiring takes place in those agencies (both new positions and staff replacements), the pool of potential trainees for these courses will dwindle.



RWIS = Road Weather Information System.

Figure 20. Graph. Performance Measure 22 – number of participants attending Road Weather Management Program-related courses held by the Consortium for Intelligent Transportation System Training and Education.

Figure 20 includes the participants of both independent-study and instructor-led versions of each of the three courses. While the instructor-led courses take place on fixed dates once or twice a year, the independent-study courses can be taken at the participants' own pace at any time throughout the year; for this reason, each data set is presented more broadly across a time span of 2 years. It is difficult to determine the reason for this drop in attendance without enough long-term data trends, but some evaluations of the courses tended to revolve around a common criticism that the online nature of the courses makes the content and delivery less effective.

It is also important to consider that the RWM-related courses offered from year to year may easily change depending on what topics are of pressing concern at a particular time. While some courses may see declines in attendance, others may see increases by corresponding amounts. In other words, it is difficult to gauge the nationwide interest in RWM programs as a whole by looking at only a few specific courses. Furthermore, a decline in "popularity" could simply be due to external factors such as busy work seasons or a re-prioritization of resources, rather than a general lack of interest in a certain topic. For example, while CITE courses saw a decline in attendance for RWMP-related online courses, the number of agencies participating in RWMP Road Weather Regional Roundtables (webinars) increased, as show in Table 2.

Table 2. Number of State transportation agencies participating in Road Weather Management Program webinars.

Date	Number of Agencies
December 2015	17
March 2016	30
October 2016	35

Furthermore, a total of 384 participants – representing all 50 State DOTs – took part in the 7 EDC-4 Weather-Savvy Roads (WSR) summit meeting sessions held in Baltimore, Minneapolis, Albany, Austin, Orlando, Portland, and Sacramento during October and November 2016. The attendance at EDC summit meetings was not a metric assessed in the previous iteration of this report due to WSR being a recent initiative by the Federal Highway Administration (FHWA) RWMP in 2016.[15]

Road Weather Management Engagement with Stakeholders in Public Conferences

RWM-related workshops and conferences vary and evolve over time and do not necessarily keep the same name, sponsor, location, or topic. For this reason it is not always easy to reach conclusions about RWM capacity building through direct comparisons of specific conferences; furthermore, collection of attendance information is not always consistent and reliable from year to year. One can, however, try to get a general sense of nationwide interest and involvement in various RWM topics by examining a broad array of reported attendance data across multiple years. RWMP representatives (staff and contractors) also provide presentations, briefings, and demonstrations at various meetings, site visits, or venues – extending the program's reach

15 FHWA, Center for Accelerating Innovation, "EDC News," 10/27/2016. Available at: https://content.govdelivery.com/accounts/USDOTHFL/bulletins/16db06f

beyond its own activities. This measure indicates the broader presence that RWMP holds in the transportation and weather community. In the 2015-2017 timeframe, RWMP was represented by program staff or support contractors as shown in Table 3. Attendance data was not collected in the previous iteration of this report, examining the 2013-2014 period.

Table 3. Meetings with Road Weather Program representation.

Year	Road Weather Program Activities 2015-2017	Number of Participants	Number of State Agencies
2015	American Meteorological Society (AMS) Summer Community Meeting, Raleigh, NC, August, 2015	250	N/A
2015	Transportation Research Board (TRB) Climate Resilience, Washington, DC, September 2015	250	15
2015	National Weather Service (NWS) Central Region Meteorologist/Hydrologist-in-Charge Meeting, Kansas City, MO, May, 2015	150	0
2015	AMS 2015 Annual Meeting, Phoenix, AZ, January, 2015	60	0
2015	NWS National Winter Weather Meeting, College Park, MD, August, 2015	50	0
2015	NWS Fall Strategy Meeting, Silver Spring, MD, October, 2015	30	0
2015	Aurora Pooled Fund Board Meeting, Reno NV, March 2015	25	18
2015	American Geophysical Union Fall Meeting, San Francisco, CA, December, 2015	20	0
2015	Colorado Department of Transportation (DOT) Pathfinder Meeting, Denver, CO, December, 2015	20	1
2015 Subtotal		**855**	**N/A**
2016	American Association of State Highway and Transportation Officials Subcommittee on Maintenance, Las Vegas, NV, July 2016	150	50
2016	AMS Washington Forum, Washington, DC, April 2016	125	N/A
2016	TRB Int'l Conf. on Surface Transp. Wx and Winter Maintenance, and SIRWEC, Fort Collins, CO, April 2016	120	8
2016	AMS Forum on Observing the Environment from the Ground Up, Washington, DC, March, 2016	100	0
2016	AMS 2016 Annual Meeting, New Orleans, LA, January, 2016	70	0
2016	Automatic Vehicle Location /GPS Peer Exchange, Sacramento, CA, October, 2016	50	10
2016	NWS / Federal Highway Administration Directors Briefing, Silver Spring, MD, August, 2016	50	0

Table 3. Meetings with Road Weather Program Representation (continued).

Year	Road Weather Program Activities 2015-2017	Number of Participants	Number of State Agencies
2016	Every Day Counts (EDC)-4 Summit, Minneapolis, MN, October, 2016	35	9
2016	Aurora Spring Board Meeting, Phoenix, AZ April 2016	25	18
2016	EDC-4 Summit Meeting, Albany NY, November 2016	24	7
2016	Capitol Hill briefing on winter weather forecasting/impacts (AMS Policy Program), Washington, DC, March, 2016	20	1
2016 Subtotal		**769**	**N/A**
2017	AMS 2017 Annual Meeting, Seattle, WA, January, 2017	80	N/A
2017	Aurora Pooled Fund Meeting, Salt Lake City, UT, April 2017	27	19
2017	Chicago AMS Stakeholder Meeting, Chicago, IL January 2017	17	5
2017 Subtotal		**124**	**N/A**

N/A = not available.

Chapter 5. Partnerships and Stakeholder Collaboration

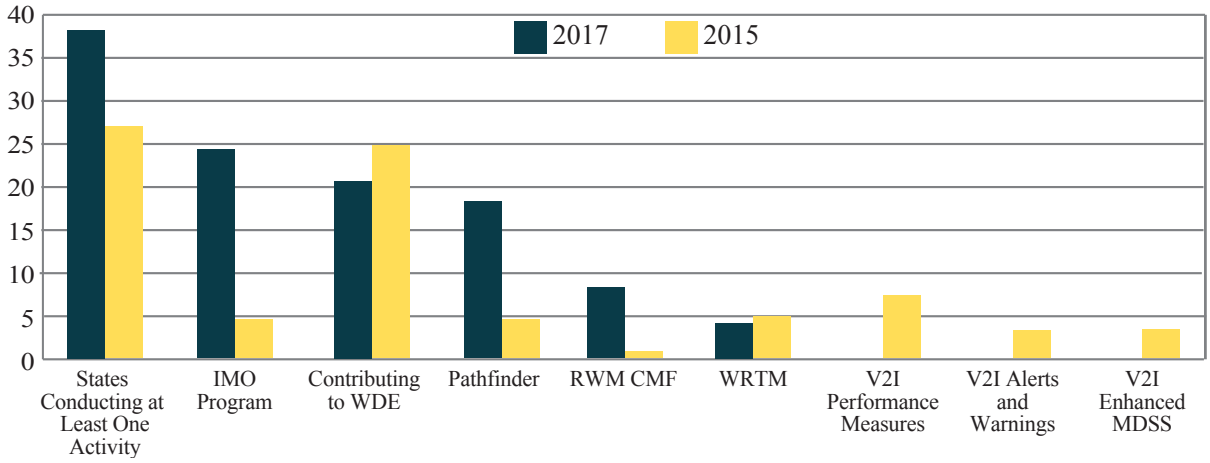
OVERVIEW

Through partnerships and stakeholder collaboration, the Road Weather Management Program (RWMP) utilizes a multi-disciplinary approach to address road weather challenges. By partnering with State departments of transportation (DOT) on research projects and attending and presenting at conferences, workshops, or meetings, the RWMP strives to build partnerships that will advance road weather innovations and practices. RWMP promotes data sharing and information exchange opportunities in order to create a collaborative and comprehensive road weather program. This chapter highlights the extent to which the RWMP is fostering and encouraging effective partnerships and stakeholder collaboration.

PERFORMANCE FINDINGS

Participation in Road Weather Program Research and Development Activities

Information sharing and collaboration are fundamental to road weather management. One way RWMP is facilitating these is by partnering with State and local transportation agencies to advance various research and development (R&D) projects. Performance Measure 1 captures this information and includes initiatives such as the Pathfinder Project, the RWMP Capability Maturity Framework (CMF), the Weather Data Environment Integrated Mobile Observations (IMO) Program, vehicle-to-infrastructure (V2I) application development efforts, and weather responsive traffic management (WRTM) implementation support activities.



RWM = Road Weather Management. CMF = Capability Maturity Framework. IMO = Integrated Mobile Observations. MDSS = Maintenance Decision Support System. V2I = vehicle-to-infrastructure. WRTM = weather responsive traffic management. WDE = Weather Data Environment.

Figure 21. Graph. Performance Measure 1 – number of agencies participating in road weather research and development projects, 2017 vs. 2015 data.

Of particular note are the Pathfinder and IMO Program participation levels, which increased significantly from 2015. Both are being promoted in the Weather-Savvy Roads innovation through the Every Day Counts (EDC) initiative. Pathfinder is a perfect example of the importance and efficiency of collaborative efforts. The National Weather Service (NWS), State DOTs, and support contractors work together to provide and share consistent and situation-appropriate road weather information. These partnerships then allow for better and more accurate information to be conveyed to the public on weather impacts to the transportation system. Overall, the number of States that are conducting at least one R&D activity has increased by approximately 52 percent (from 27 to 41) from the last update report.

Participation in Meteorological Assimilation Data Ingest System

Another example of fostering stakeholder collaboration and partnerships by the RWMP is supporting National Oceanic and Atmospheric Administration (NOAA) by working with State DOTs to sign data-sharing agreements and ensure data quality by integrating quality checking algorithms into the system. Performance Measure 10 tracks the number of State DOTs that are participating in the Meteorological Assimilation Data Ingest System (MADIS) program by signing a data sharing agreement and providing real-time data to MADIS.

From 2016 to 2017, the participation of State DOTs has increased from 12 to 21, a 75 percent increase.

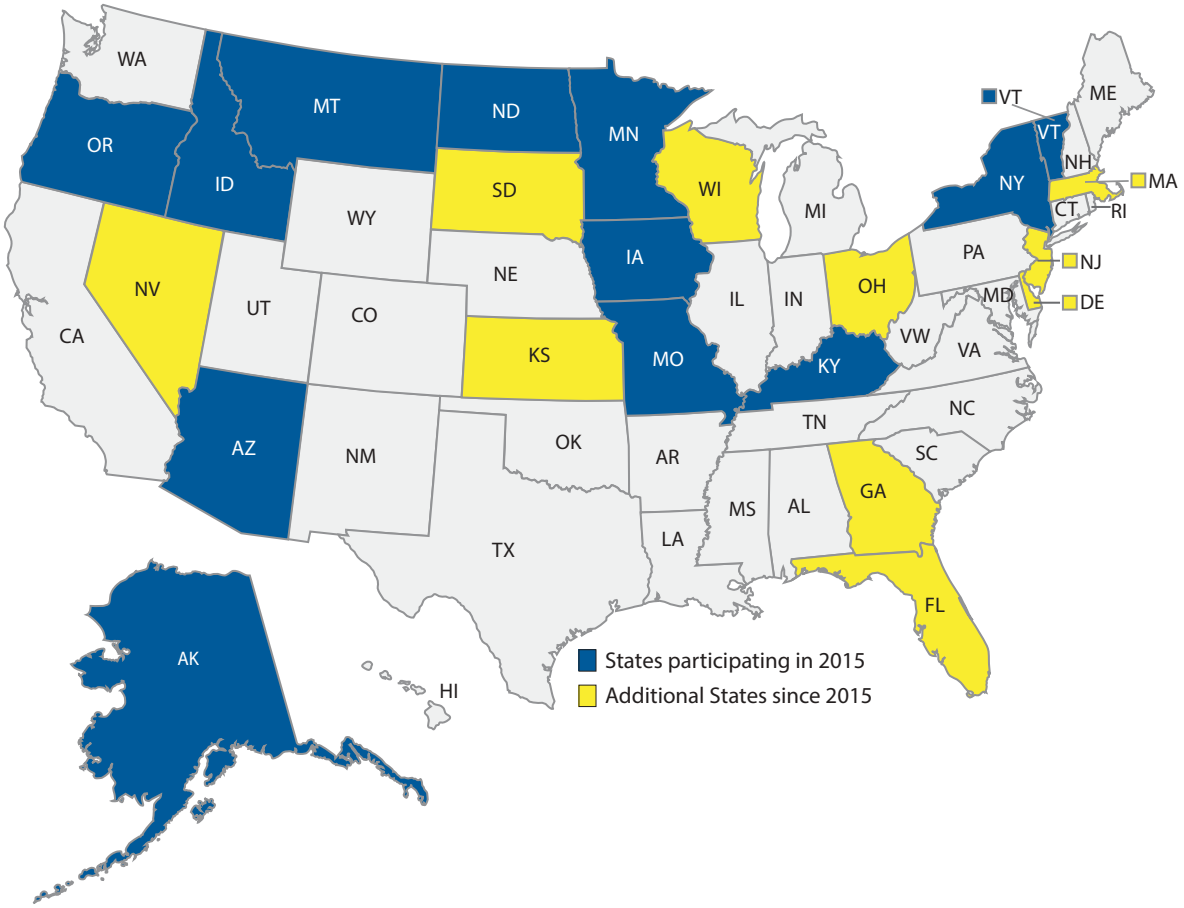


Figure 22. Map. 2017 State participation in the Meteorological Assimilation Data Ingest System (MADIS) Program.

Engagement with National Weather Service

A similar performance measure, which has also shown notable growth in RWM partnerships in recent years, tracks the number of agencies that coordinate with their local weather forecast offices for assistance in road weather management and operations (Performance Measure 18, summarized in Figure 23).

NWS = National Weather Service

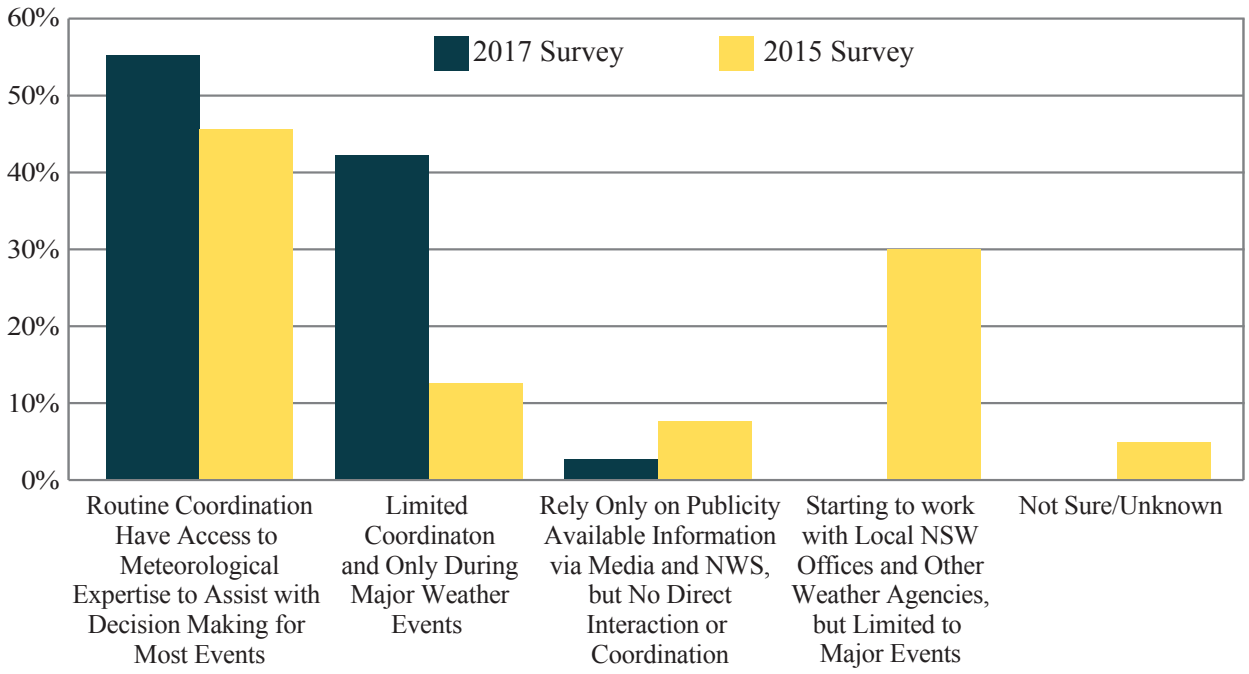


Figure 23. Chart. Level of coordination between State departments of transportation and National Weather Service local forecast offices.

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 NWS local forecast office, it reflects a commitment to enhancing the performance of road weather management and operations activities. Almost all respondents (98 percent) reported at least some coordination with the NWS local forecast office, with 55 percent saying they routinely coordinate and have access to meteorological expertise. This represents a large increase from 2015, where one-third of the respondents were just starting to work with the NWS.

Chapter 6. Recommendations and Conclusions

The Road Weather Management Program (RWMP) performance update continues to benefit from strong stakeholder input and the various data maintained by the program. The survey conducted under this update continued to get a high response rate (82 percent) from State departments of transportation (DOT), providing a comparable dataset to the 2015 report. Survey results and key findings by performance measure are provided in Appendices A and B.

Based on the results of the 2017 performance measure update, the following five recommendations are identified for consideration by the RWMP program:

1. ***Create a national database of State DOT performance measures and reports***. The findings from this update show a significant number of States starting to consider performance measures, and several report that they already have a process. A national repository of performance measures and reports used by State DOTs is helpful for a State that is beginning to consider implementing performance measures. While it is possible to obtain these reports on a State-by-State basis, collecting them in one location will allow for more detailed understanding of the different approaches used by State DOTs.
2. ***Reengage in Maintenance Decision Support System (MDSS) outreach.*** In recent years, the Federal Highway Administration (FHWA) has not focused on promoting MDSS deployment. With MDSS maturing, it was a rational approach to move away from MDSS towards new research priorities. However, in both 2015 and 2017, there is evidence of stagnation of MDSS adoption. This might warrant a re-examination of the challenges associated with deploying MDSS and options for sharing best practices and case studies in this area. With emerging technologies like Integrated Mobile Observations (IMO), the value of MDSS as a tool to ingest complex data streams and provide meaningful input to road weather management (RWM) operations and maintenance staff increases.
3. ***Continue to showcase the value of vehicle-to-infrastructure (V2I) application deployment.*** The report finds that V2I deployment is still in early stages. With emerging guidelines on Connected Vehicle-Enabled Weather Responsive Traffic Management (CV-WRTM) and other connected vehicle efforts underway nationally, the FHWA RWMP should continue to promote weather-related use cases in V2I deployment. Ongoing CV-WRTM implementations and the Wyoming connected vehicle pilot offer some near-term opportunities.
4. ***Develop a plan for accelerating awareness and deployment of weather-responsive traffic analysis tools.*** Unfortunately, as the report and the previous update reveals, there is very little awareness or use of some of the analytical tools developed by the road weather management program. The RWMP's early efforts in conducting empirical studies on traffic flow during inclement weather and microscopic analysis of traffic flow during adverse weather provide valuable information to agencies deploying WRTM. Existing tools like the Weather-Responsive Traffic Estimation and Prediction System and future tools like the

Integrated Road Condition Modeling and Prediction System offer real opportunities to RWM stakeholders for decision support during stressful operating conditions. This low level of awareness is not particular to RWMP; other tools focused on travel reliability have also seen only a low level of uptake among the stakeholder community. With the variety of tools available, it is also difficult for a stakeholder to identify the right tool for the right analysis. To this end, a primer on the use of weather-responsive analysis tools by road weather management professionals is needed.

5. ***Sustain Weather Savvy Roads (WSR) interest and implementation plans.*** Significant increases in State DOT participation have been noted due to the interest in the WSR initiative. A large number of States have expressed interest in implementing either IMO or Pathfinder or both aspects of the initiative. Maintaining the momentum and continuing to monitor and support implementation plans beyond the Every Day Counts-4 initiative period is critical to ensuring that these efforts are mainstreamed within the organization and the advances can meaningfully result in capability maturity at the agencies. A significant part of future updates of the report will likely be based on how State DOTs have moved forward in the implementation of IMO and Pathfinder activities.

To conclude, the current update of the performance measure continues to show a vibrant stakeholder community, new and strengthened partnerships, and sustained use of available technologies for road weather management. The greatest advancements in program performance are a result of the focus brought forward by the Weather Savvy Roads initiative, though work still needs to be done on educating the stakeholder community about the use of decision-support, analysis, and modeling tools. National level trends continue to show the magnitude of the problem, but few case studies were observed documenting benefits since the previous update. As noted in the recommendations, interest among the stakeholder community in performance measurement, V2I deployment, and WSR offer new opportunities for the program to engage and encourage new State DOTs and partners to be part of the national road weather management community.

Appendix A. State Department of Transportation Survey Summary

The following pages show the State department of transportation (DOT) survey questions and summary.

➤ Q4. What are your agency's sources of weather and road weather information? (Check all that apply.)

Associated PM: Number of State DOTs that subscribe to road weather products and services.

Table 4. State department of transportation survey question 4 and associated responses.

Answer Options	Response Percent	Response Count
Fixed Agency Sensors (road weather information system)	95.0%	38
Mobile Agency Sensors	55.0%	22
Private Weather Service Providers	72.5%	29
Agency Field Personnel	75.0%	30
Public / Social Media	47.5%	19
Federal Aviation Administration Products (automated surface observing system/automated weather observing system)	25.0%	10
National Weather Service Products	95.0%	38
National Oceanic and Atmospheric Administration Meteorological Assimilation and Data Ingest System	17.5%	7
U.S. Geological Survey Earthquake Alerts	10.0%	4
Not Sure / Unknown	0.0%	0
Other	5.0%	2
Answered Question	**40**	
Skipped Question	**0**	

ASOS = Automated Surface Observing System. AWOS = Automated Weather Observation System. FAA = Federal Aviation Administration. NOAA = National Oceanic and Atmospheric Administration. RWIS = Road Weather Information System. USGS = United States Geological Survey.

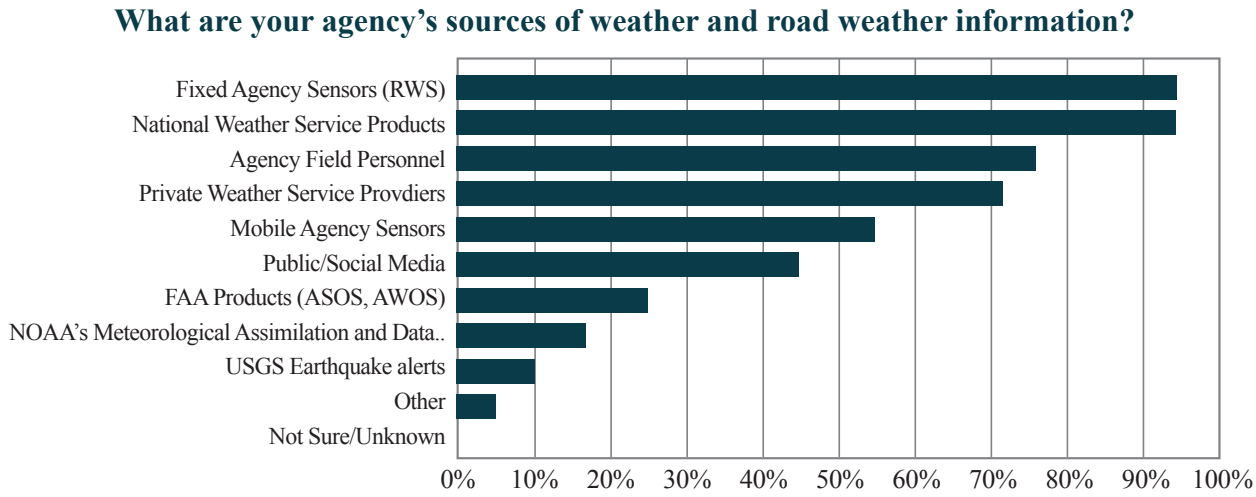


Figure 24. Chart. Responses from State department of transportation survey question 4.

Other responses to Question 4 included:

- Weather Senty DTN.
- Traffic Operations CCTV cameras.

➤ 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.

Table 5. State department of transportation survey question 5 and associated responses.

Answer Options	Response Percent	Response Count
Yes	57.5%	23
No	42.5%	17
Not Sure / Unknown	0.0%	0
Answered Question	**40**	
Skipped Question	**0**	

➤ Q5.1. 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.

Table 6. State department of transportation survey question 5.1 and associated responses.

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	Total	% Collecting Mobile Observations
Plow Status and Material Usage	5	8	3	4	2	1	23	87.0%
Atmospheric weather data (air temperature, relative humidity, etc.)	2	7	4	7	3	0	23	87.0%
Road weather conditions data (pavement temperature, etc.)	3	7	4	7	2	0	23	91.3%
Answered Question	**23**							
Skipped Question	**0**							

➤ Q6. Has your agency developed applications or tools that use real-time mobile data from vehicle fleets?

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

Table 7. State Department of transportation survey question 6 and associated responses.

Answer Options	Percentage
Yes	32.5%
No	20.0%
Considering, but Not Yet Developed	47.5%
Not Sure / Unknown	0.0%
Answered Question	**40**
Skipped Question	**0**

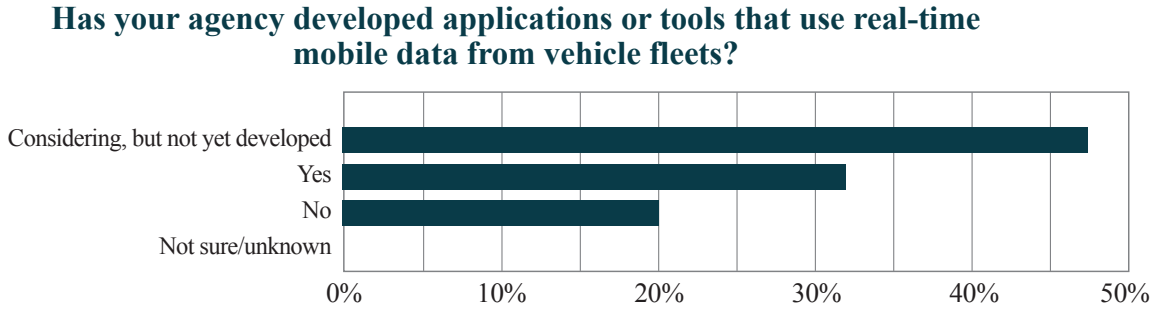


Figure 25. Chart. Responses from State department of transportation survey question 6.

➤ Q7. Has your agency developed applications or tools that leverage infrastructure-to-vehicle (I2V) or vehicle-to-infrastructure (V2I) connectivity?

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

Table 8. State department of transportation survey question 7 and associated responses.

Answer Options	Percentage
Yes	17.5%
No	37.5%
Considering, but Not Yet Developed	42.5%
Not Sure / Unknown	2.5%
Answered Question	40
Skipped Question	0

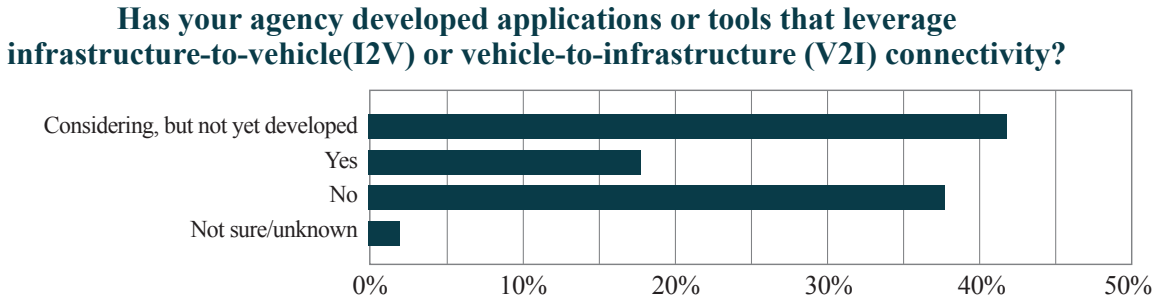


Figure 26. Chart. Responses from State department of transportation survey question 7.

➤ Q8. Approximately 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.

Table 9. State department of transportation survey question 8 and associated responses.

Total number	2424
Answered Question	40
Skipped Question	0

➤ Q9. Describe how you use your ESS data. (Check all that apply).

Associated PM: Number of State DOTs reporting the use of ESS in operations and maintenance activities.

Table 10. State department of transportation survey question 9 and associated responses.

Answer Options	Percentage
Provide Current Conditions to Traveler Information Systems	70.0%
Input for Segment-Level Forecasts	50.0%
Support Traffic Management and Maintenance Decision-Making (e.g., Maintenance Decision Support System)	72.5%
Do Not Use Environmental Sensor System Data	7.5%
Not Sure / Unknown	5.0%
Other	7.5%
Answered Question	40
Skipped Question	0

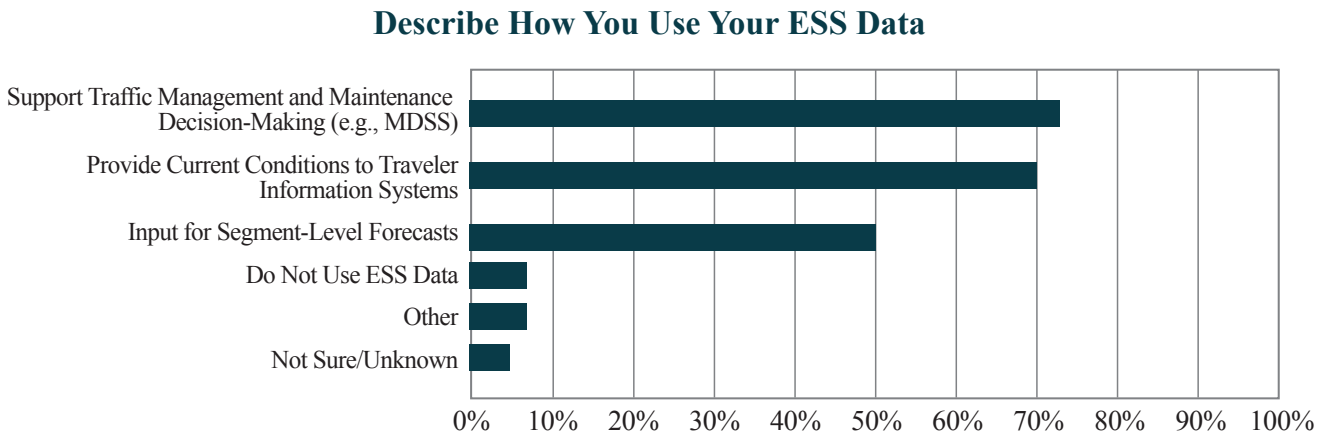


Figure 27. Chart. Responses from State department of transportation survey question 9.

Other responses to Question 9 included:

- Operation of variable speed limit systems.
- Provide current conditions to maintenance personnel.
- Performance monitoring/research.

➤ Q10. Describe the level of deployment in your agency of the following road weather information strategies.

Associated PM: Number of States disseminating weather advisory and other road weather information to travelers.

Table 11. 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	Total
Atmospheric Weather Information on Dynamic Message Signs	42.1%	21.1%	36.8%	0.0%	100.0%
Road Condition Information on Dynamic Message Signs	50.0%	35.0%	12.5%	2.5%	100.0%
Road Condition Information on Highway Advisory Radio	27.0%	27.0%	32.4%	13.5%	100.0%
Road Condition Information on Agency-Hosted Social Media (Twitter, Facebook, etc.) or Mobile Applications	60.5%	26.3%	13.2%	0.0%	100.0%
Road Condition Information on Agency-Hosted Websites or 511 Phone Systems	77.5%	15.0%	7.5%	0.0%	100.0%
Answered Question	40				
Skipped Question	0				

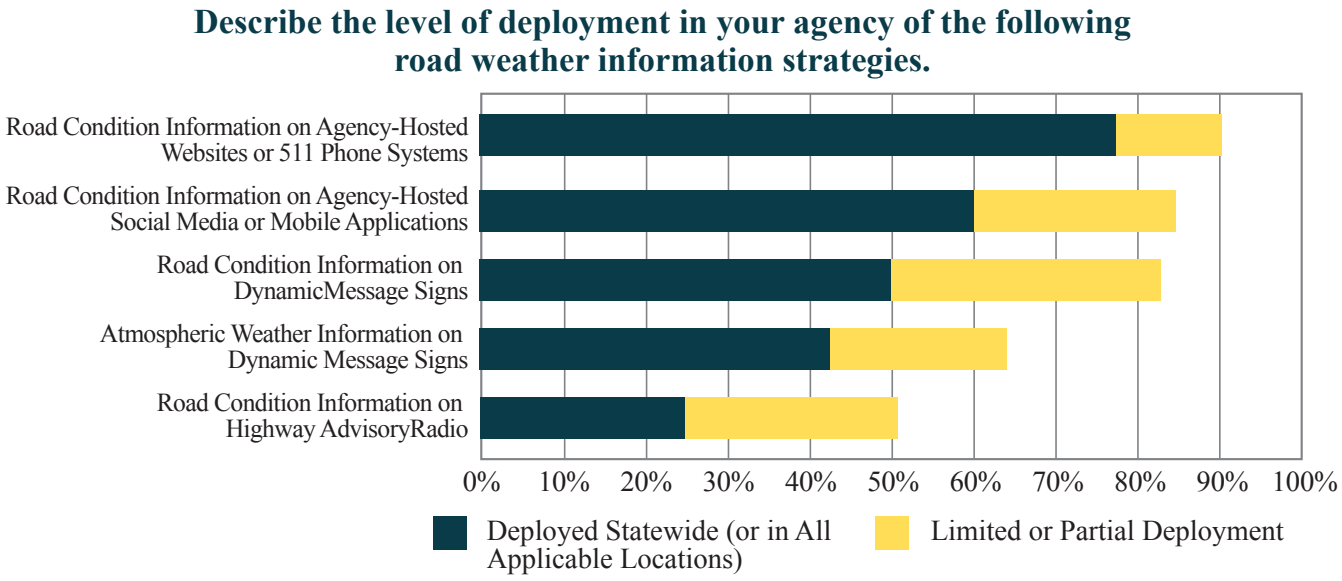


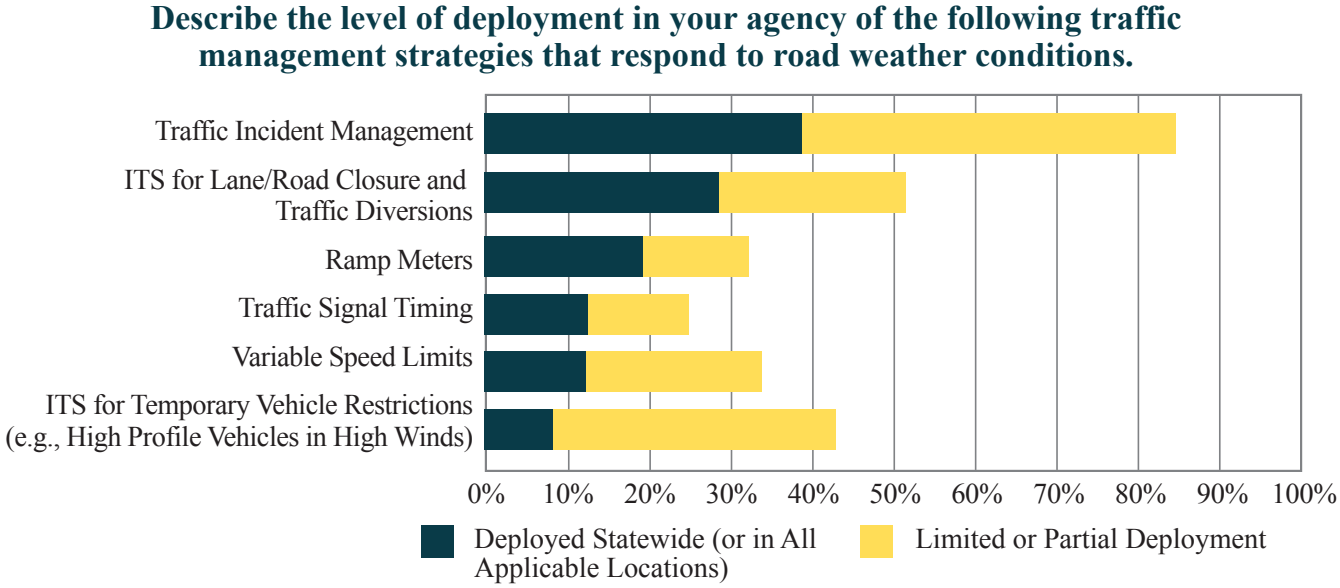
Figure 28. Chart. Responses from State department of transportation survey question 10.

➤ Q11. Describe the level of deployment in your agency of the following traffic management strategies that respond to weather conditions.

Associated PM: Number of agencies using control and treatment strategies during weather events.

Table 12. State department of transportation survey question 11 and associated responses.

Answer Options	Deployed Statewide (or in all applicable locations)	Limited or Partial Deployment	Not Yet Deployed	Not Sure/ Unknown
Ramp Meters	18.4%	13.2%	60.5%	7.9%
Traffic Signal Timing	13.2%	13.2%	63.2%	10.5%
Variable Speed Limits	10.8%	24.3%	62.2%	2.7%
Intelligent Transportation Systems (ITS) for Temporary Vehicle Restrictions (e.g., High Profile Vehicles in High Winds)	7.7%	35.9%	48.7%	7.7%
ITS for Lane / Road Closure and Traffic Diversions	28.2%	23.1%	43.6%	5.1%
Traffic Incident Management	38.5%	46.2%	10.3%	5.1%
Answered Question	39			
Skipped Question	1			



ITS = intelligent transportation systems.

Figure 29. Chart. Responses from State department of transportation survey question 11.

➤ Q12. Describe your level of interactions with the National Weather Service (NWS) 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.

Table 13. State department of transportation survey question 12 and associated responses.

Answer Options	Percentage
Rely Only on Publicity Available Information via Media and National Weather Service, but No Direct Interaction or Coordination	2.5%
Limited Coordination and Only During Major Weather Events	42.5%
Routine Coordination. Have Access to Meteorological Expertise to Assist with Decision Making for Most Events	55.0%
Not Sure / Unknown	0.0%
Answered Question	40
Skipped Question	0

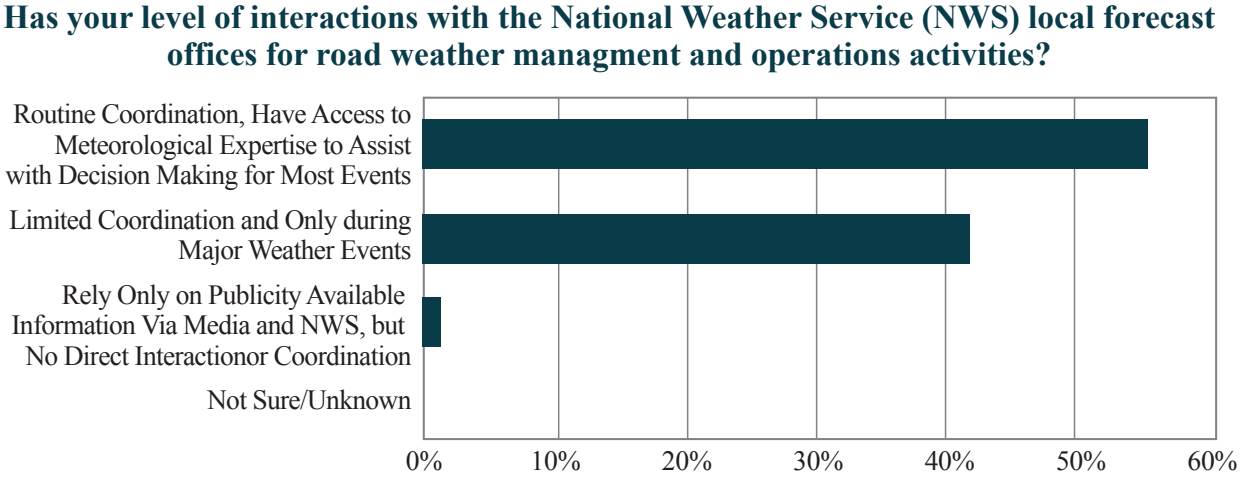


Figure 30. Chart. Responses from State department of transportation survey question 12.

➤ 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.

Table 14. State department of transportation survey question 13 and associated responses.

Answer Options	Percentage
Yes - Use a maintenance decision support system (MDSS) Statewide	20.0%
Yes - Use an MDSS, but Not Statewide	15.0%
No - Need an MDSS, but Currently Do Not Have a System	22.5%
No - Do Not Need an MDSS	35.0%
Not Sure / Unknown	7.5%
Answered Question	40
Skipped Question	0

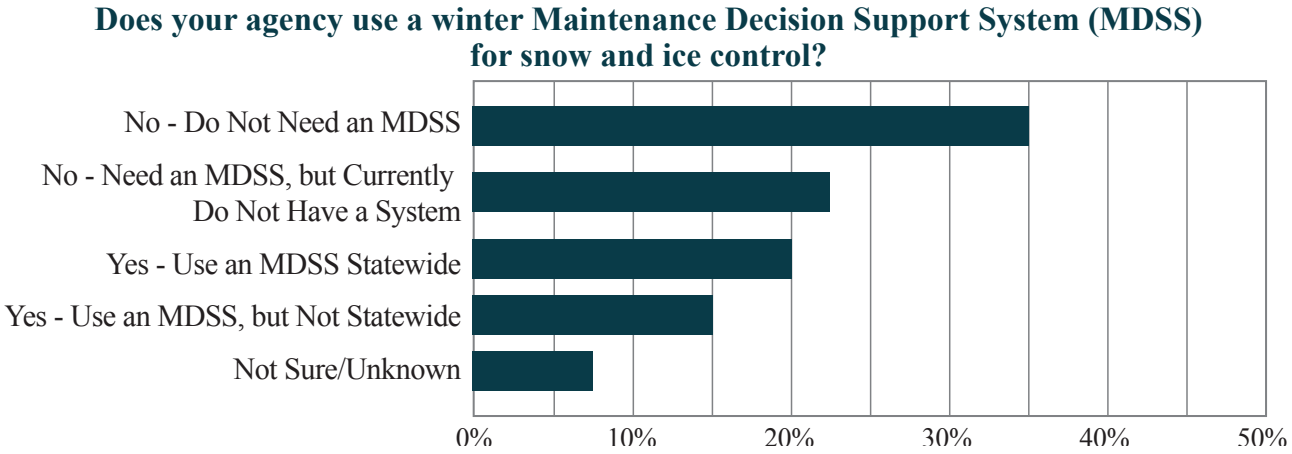


Figure 31. Chart. Responses from State department of transportation survey question 13.

➤ Q13.1. If you need an MDSS, but currently do not have a system, please provide the reason(s) for the lack of implementation.

Responses to Question 13.1 included:

- Hesitancy in the upper management to indulge in MDSS but would support some program to take all of our winter related data and make it easier to review for our maintenance crews to make decisions on operational decisions.
- Currently working under ED4 for an institutionalized RWMS to include MDSS.
- Cost, lack of funding, and lack of sufficient support infrastructure.
- Currently investigating the development and implementation of a maintenance management system in which MDSS will be a component.

- Withdrew from an MDSS group after information provided was suspect due to the fact our snow is much different than the Midwest and MDSS called for much more use of deicers than we felt were needed. (California.)
- Due to the lack of input from vehicles, a system of this magnitude would largely go unused at this point, relative to the summary reports for event performance. Currently utilize tactical and strategic weather reports, provided by an outside vendor, to support operational decision making before and during an event. Once we can support a vehicle based information system, to include the monitoring of plowing and spreading, we would, in all likelihood, employ an MDSS.
- We currently have our protocol with regard to winter maintenance operations and are looking into it.
- Winter weather events have limited impacts and don't happen very often.

➤ Q14. Does your agency use other decision support tools (besides a winter MDSS) for road weather management. If so, how are they used? (Check all that apply)

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

Table 15. State department of transportation survey question 14 and associated responses.

Answer Options	Percentage
None	10.0%
Providing Traveler Information	72.5%
Coordination with Other Jurisdictions / Agencies	52.5%
Supporting Non-Winter Maintenance Activities (e.g., Maintenance Scheduling, Construction Coordination)	42.5%
Traffic Control and Management (e.g., Speed Limit Determination, Signal Timing Plans, Ramp Metering Rates)	20.0%
Setting Seasonal Load Restrictions	12.5%
Not Sure / Unknown	7.5%
Other	7.5%
Answered Question	40
Skipped Question	0

Does your agency use other decision support tools (besides a winter MDSS) for road weather mangement? If so, how are they used?

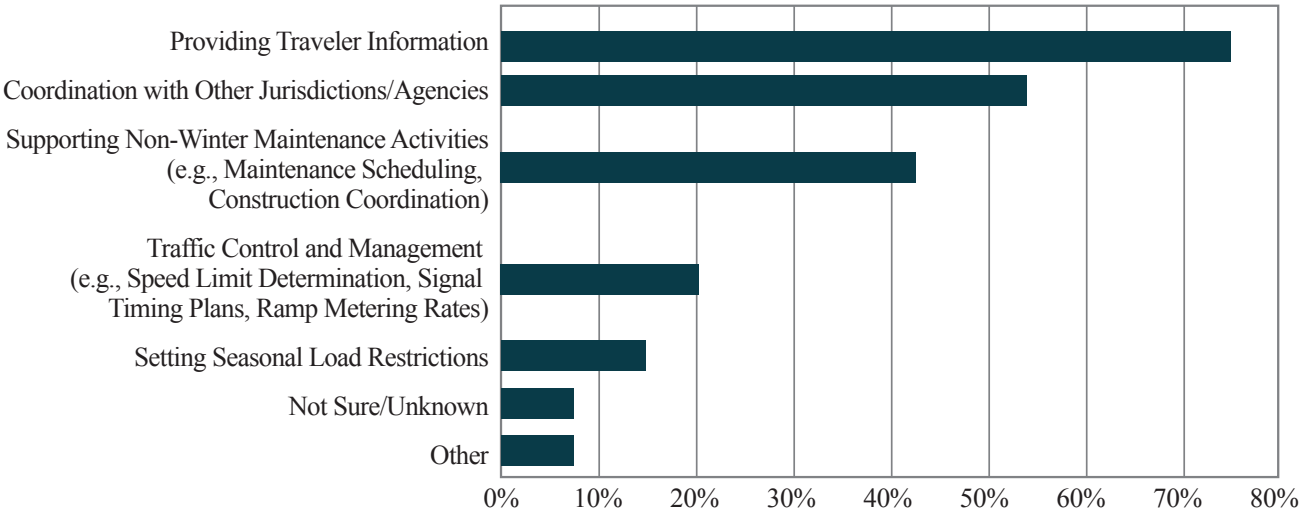


Figure 32. Chart. Responses from State department of transportation survey question 14.

Other responses to Question 14 included:

- RWIS, contracted weather service, storm monitors.
- Use of PikAlert in near future.
- Emergency Management software for all transportation related weather events (hurricanes, severe weather, etc.).

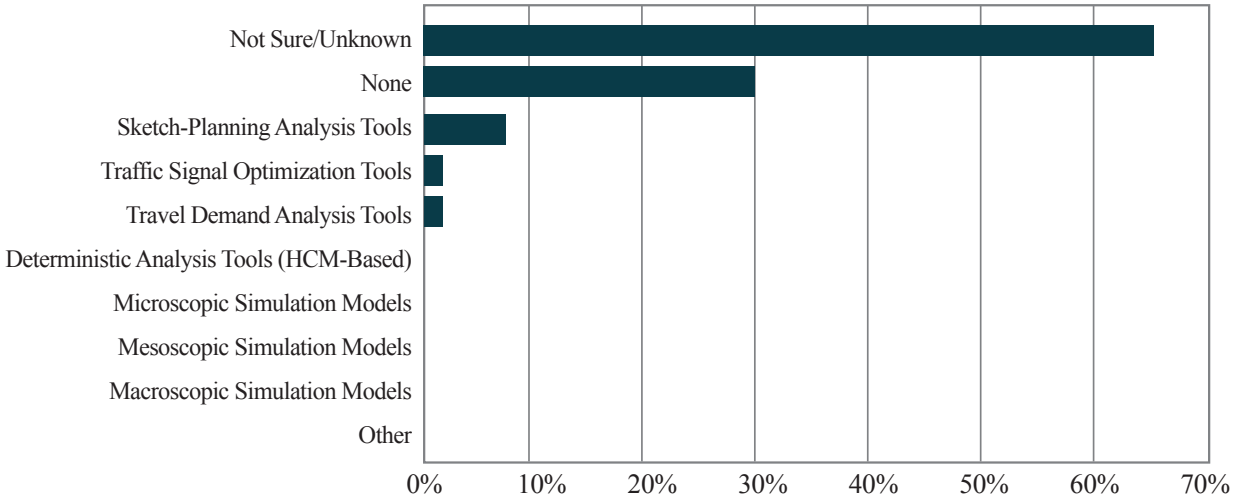
➤ Q15. What types of traffic analysis and simulation tools does your agency use for planning and evaluating road weather management strategies? (Check all that apply)

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

Table 16. State department of transportation survey question 15 and associated responses.

Answer Options	Percentage
None	30.0%
Sketch-Planning Analysis Tools	7.5%
Travel Demand Analysis Tools	2.5%
Macroscopic Simulation Models	0.0%
Mesoscopic Simulation Models	0.0%
Microscopic Simulation Models	0.0%
Deterministic Analysis Tools (Highway Capacity Manual-Based)	0.0%
Traffic Signal Optimization Tools	2.5%
Not Sure / Unknown	65.0%
Other	0.0%
Answered Question	40
Skipped Question	0

What types of traffic analysis and simulation tools do your agency use for planning and evaluating road weather management strategies?



HCM = Highway Capacity Manual.

Figure 33. Chart. Responses from State department of transportation survey question 15.

Q16. Road weather management supports sustainable transportation systems. Which statements below pertain to your agency regarding the role of road weather management in sustainable transportation? (Check all that apply.)

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

Table 17. State department of transportation survey question 16 and associated responses.

Answer Options	Percentage
Have a Dedicated Road Weather Management Program	33%
Have Defined Sustainability Goals for Road Weather Management that are Monitored Regularly	33%
Have a Documented Materials Management Plan	51%
Own and Operate a Road Weather Information System	74%
Have a Documented Standard of Practice or Standard Operating Procedure for Snow and Ice Control	79%
None of These Statements are Supported	3%
Not Sure / Unknown	8%
Answered Question	39
Skipped Question	1

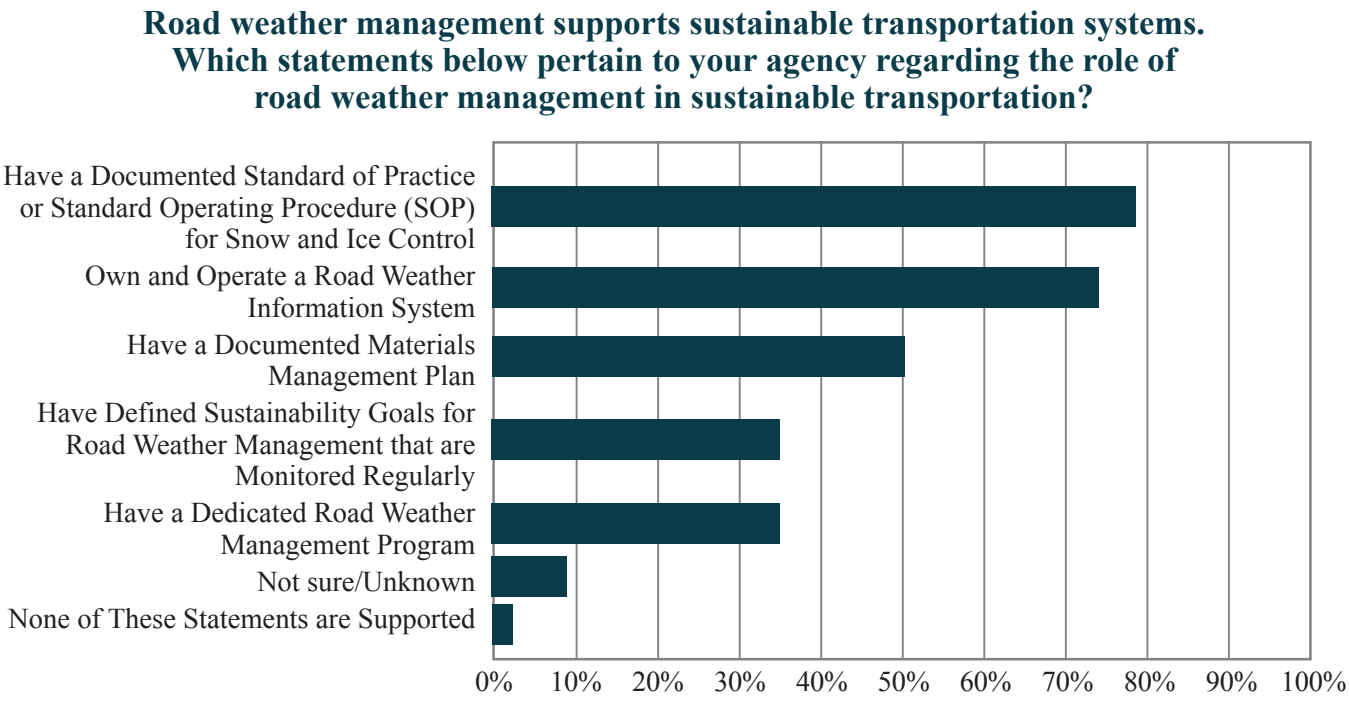


Figure 34. Chart. Responses from State department of transportation survey question 16.

➤ 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.

Table 18. State department of transportation survey question 17 and associated responses.

Answer Options	Percentage
Conducted a Vulnerability / Risk Assessment for Road Weather Management Infrastructure	18%
Developed / Implemented Process for Responding to Extreme Weather	50%
Developed / Implemented Resiliency Plans for Road Weather Management Infrastructure	18%
Participated in State DOT Resilience Adaptation Planning Activities	21%
Agency Has Not Participated in Development of Adaptation Practices	16%
Not Sure / Unknown	37%
Answered Question	38
Skipped Question	2

How has your agency participated in extreme weather or resilience adaptation practice?

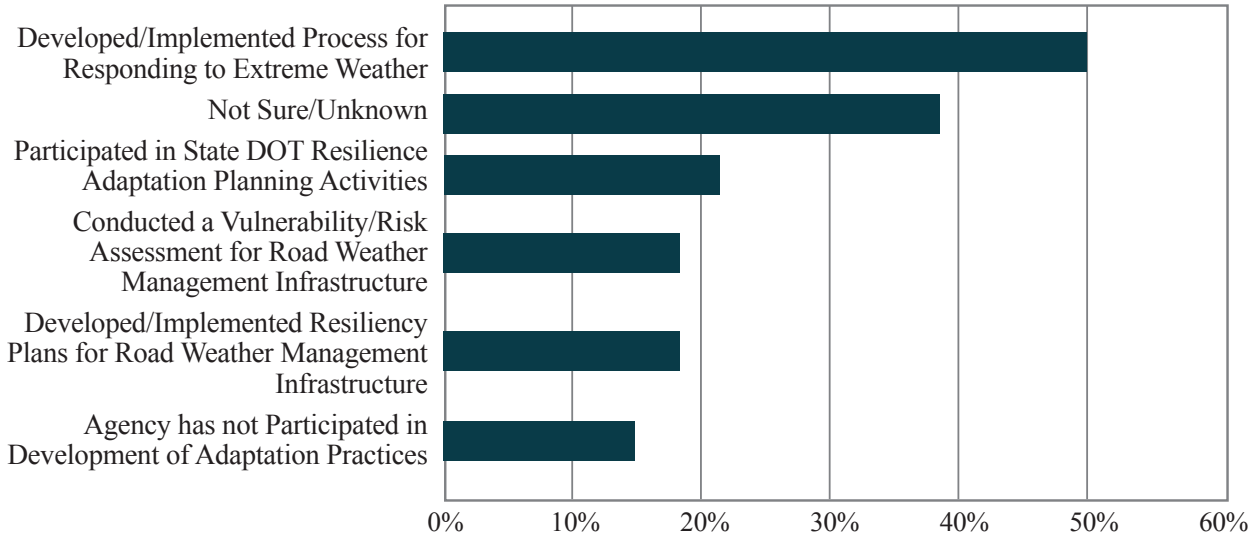


Figure 35. Chart. Responses from State department of transportation survey question 17.

➤ Q18. Does your agency 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.).

Table 19. State department of transportation survey question 18 and associated responses.

Answer Options	Percentage
Yes	56%
No	33%
Not Sure/Unknown	10%
Answered Question	39
Skipped Question	1

Does your agency collect and report road weather performance measures?

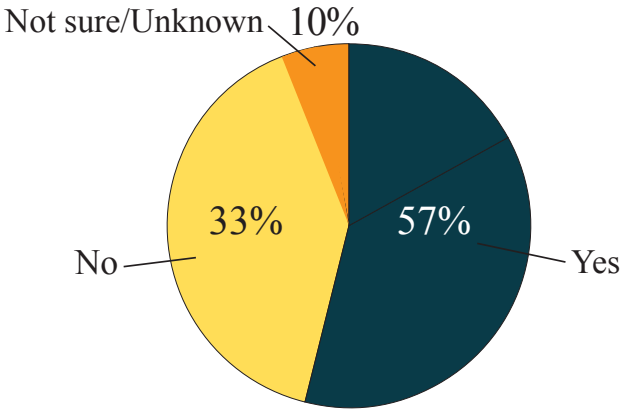


Figure 36. Chart. Responses from State department of transportation survey question 18.

➤ Q18.1. Please provide a description, reference, and/or link to your agency's road weather performance measures.

- Several internal reports and programs. Public-facing versions here:
  - http://www.iowadot.gov/performance/winter_operations.html
  - http://iowadot.maps.arcgis.com/apps/webappviewer/index.html?id=fa8e84ffc4694acb9f06c054798af562
- We are starting to utilize the RWIS data and the level of grip after the storm to establish performance measures. We have begun collecting data and evaluating this winter.
- An internal report is run to evaluate the recovery time of expected travel speeds following the conclusion of a winter weather event. It combines RWIS and traffic speed data synthesis that are used to evaluate our performance and measure our ability to achieve success under one of our Critical Success Factors.
  1. Percentage of time grip is safe when there is a surface layer at below 32 degrees
  2. Percentage of time RWIS sites are on line (goal is 95%)
  3. Index quantifying response to winter storms
- We report lag/lead metrics for LOS grading statewide, on I-25 through Denver Metro, and on I-70 from Golden to Dotsero. These grades are reported out every two months to executive management.
- They are published internally only.
- We measure snow and ice clearance times by County.
- We have a tracker that measures the time it takes from the last of the precipitation to reach the performance objectives of winter operations. www.modot.org
- http://www.dot.state.mn.us/measures/index.html
- We have just recently added sensors to use the Idaho performance measurement system, but haven't implemented the system operationally.
- Dashboard, winter maint reports, and seasonal summaries
- Dashboard and Precise GPS monitoring
- http://www.state.nj.us/transportation/about/winter/expenditures.shtm
- Not published at this time, plans to be published in near future.
- The UDOT Snow and Ice Performance Measure was built in-house using strictly data from RWIS sites. This measure uses a storm severity index. The winter severity index can be calculated.
  - http://www.udottraffic.utah.gov/ForecastView/Default.aspx
  - http://udottraffic.utah.gov/forecastview/ssipdashboard.aspx
- Congestion & Mobility Performance Report (http://www.michigan.gov/mdot/0,4616,7-151-9622_11045_25024_75677---,00.html)

- Custom Reports:
    - o Time to restore pavement to normal flow after winter precip.
    - o Salt usage by lane mile per inch of snow.
    - o Winter Operations Performance (Equipment, materials, road conditions)
- Internal documents- Winter Event Tracing form. Just began using and experimenting this past winter.
- We are working on several segments utilizing recovery speed data from ATR's. This will be expanded to other areas in the future using ATR's, radar sensors, and possibly third party data in the future.

Q19. Does your agency use a "winter severity index" to compare performance across events or across years?

Associated PM: Reduction in number of tons of salt or chemical usage in the US normalized by winter severity index.

Table 20. State department of transportation survey question 19 and associated responses.

Answer Options	Percentage
Yes	41%
No	56%
Not Sure/Unknown	3%
Answered Question	39
Skipped Question	1

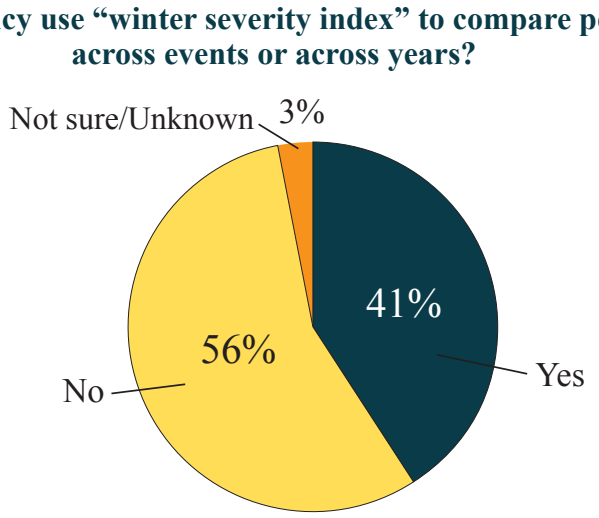


Figure 37. Chart. Responses from State department of transportation survey question 19.

Q20. Does your agency have a process for evaluating the return on investment or net benefits of road weather management investments?

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

Table 21. State department of transportation survey question 20 and associated responses.

Answer Options	Percentage
Yes	23%
No	56%
Not Sure/Unknown	21%
Answered Question	39
Skipped Question	1

Does your agency have a process for evaluating the ROI or net benefits of road weather management investments?

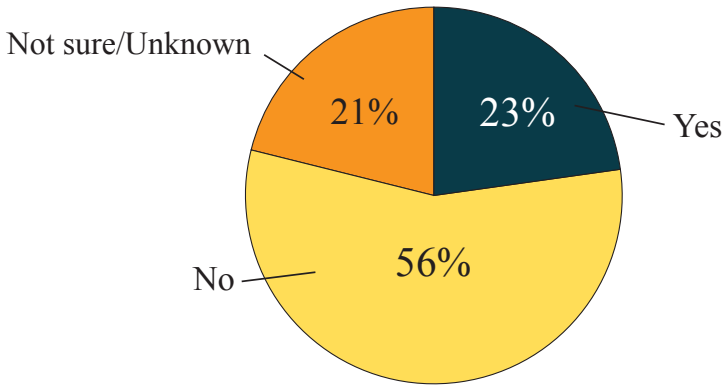


Figure 38. Chart. Responses from State department of transportation survey question 20.

➤ Q21. 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 or net benefit of their road weather management investments.

Table 22. State department of transportation survey question 20 and associated responses.

Answer Options	Percentage
Yes	92%
No	5%
Not Sure/Unknown	3%
Answered Question	39
Skipped Question	1

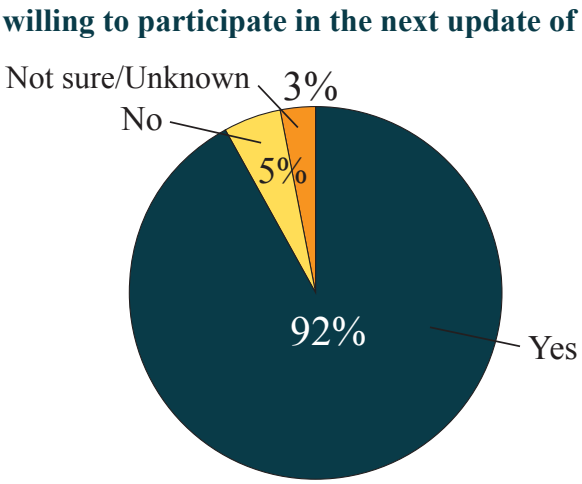


Figure 39. Chart. Responses from State department of transportation survey question 21.

Appendix B. Findings by Measure

ROAD WEATHER MANAGEMENT PROGRAM PERFORMANCE AND RESULTS

Objective 1: Build and sustain relationships with multi-disciplinary partners to expand Road Weather Management deployments.

Table 23. Summary of objective #1 performance measures.

PM #1: Number of agencies participating in road weather Research and Development R&D projects
• Eighteen (18) State DOTs are currently participating in the Pathfinder Project, including 14 new States. • Nine (9) public agencies have participated in the development and use of the RWMP Capability Maturity Framework. • Twenty-four (24) State DOTs have participated in the IMO program, a significant increase from the previous period. • Twenty-one (21) State DOTs have participated in weather data environment research activities. • Four (4) State DOTs have been involved in WRTM implementation support activities. (Again decrease) • There is no data on how many State DOTs have been involved in V2I implementation activities or how many are using the IMRCP tool. • All in all, forty-one (41) States are conducting at least one activity as compared to only twenty-seven (27) in the prior period.
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 increased from the low of 2014, with approximately half of the States attending the RWMP meetings in 2015 (27) and 2016 (24). • The WRTM meeting in 2015 attracted twenty-three (23) State DOTs. • The EDC-4 Summits held in 2016 were well-attended, with 48 States participating along with the District of Columbia and the U.S. Virgin Islands.
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.

Table 24. 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, 22 DOTs reported regularly collecting and reporting some form of road weather performance measures. Thirteen States reported they did not collect and report road weather performance measures, and four respondents were uncertain. • Sixteen (16) State DOTs reported the use of a winter severity index to compare performance across events or years.
PM #4: Number of agencies that have a process for evaluating the return on investment or net benefit of their road weather management investments
• Nine (9) States that have a process in place to evaluate ROI or the net benefits of road weather management investments. This is almost twice the number of States that had such a process in 2015 (5). • A 2014 Transportation Research Board research paper compared winter crash data on roadway segments in Idaho before and after deployment of RWIS sites and calculated a benefit-cost ratio of 22, easily justifying the investment.
PM #5: Reductions in agency costs of winter weather-related maintenance and operations activities
• While local governments have seen a reduction in expenditures for snow and ice removal between 2012 and 2013 (the latest period of data available), State government expenditures have risen in the corresponding time period – resulting in a total expenditure increase of about 13%. This slight increase in expenditure is a shift in direction from the previous decline between 2011 and 2012. • The above observations speak to the natural, unpredictable variation in weather and road weather conditions in the short run. Virginia and Pennsylvania experienced the largest increases between 2012 and 2013, spending an additional $80 million and $92 million on winter operations and maintenance, respectively. • A 2016 case study in Idaho demonstrated that equipping electronic spreader control systems on snowplow trucks and installing RWIS sites throughout the State helped lower the State's winter maintenance costs by 29 percent over three years; in fact, between 2013 and 2014, Idaho's winter maintenance expenditures were reduced by nearly $2 million.
PM #6: Reduction in number and types of fatalities and crashes attributed to adverse weather nationally
• The percentage of fatal crashes that occur during inclement weather held steady at 10% in 2014 and 2015. • The 10-year average for 2005-2014 shows almost no change in the percentage of weather-related crashes due to adverse road conditions compared to 2002-2012. • A 2016 case study on Michigan's weather responsive traveler information system Wx-INFO shows mixed results, with traffic incident rates decreasing in two regions, increasing in two regions, and staying constant in two regions.

Table 24. Summary of objective #3 performance measures (continued).

PM #7: Reduction in the extent of capacity losses and delays due to fog, snow, and ice events including freight
• Two case studies have been published since 2015. As a result of Michigan's Wx-INFO system, user delays during National Weather Service advisory and warning alerts decreased between 25 and 67% statewide; in Utah, a survey of motorist behavior during a winter storm event showed that 62% of respondents changed their schedule, 26% changed their route, and 13% decided not to travel based on information provided as a result of the Pathfinder initiative.
PM #8: Increase in travel time reliability or decrease in variability due to road weather management strategies during adverse weather scenarios
• While still few agencies track reliability measures, more research has been conducted since the prior reporting period in improving travel reliability. As an example, the Mountain-Plains consortium – sponsored by the U.S. DOT – developed a new methodology for incorporating travel times calculated from intelligent transportation system technology into Wyoming's weather condition reporting system.
PM #9: Reduction in the number of tons of salt or chemical usage in the U.S. normalized by Winter Severity Index
• There was a 20% increase in the amount of salt used for de-icing between 2013 and 2014. • Iowa reported that since the State began using a Salt Dashboard, the amount of salt used statewide has been "consistently, and often significantly" below the target. This has contributed to savings of more than $2.7 million annually since 2012. • Maryland has reduced its salt usage by 40% over the past three winters through its Statewide Salt Management Plan. • Maine's WSI factors historical snowfall data, daily snowfall amounts, ambient temperature, and liquid precipitation; the State views the WSI as a helpful tool to evaluate the effectiveness of winter maintenance equipment, crews, and methods of fighting snow.
DOT – department of transportation, 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.

Table 25. 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
• Ten (10) new States have joined the MADIS program, bringing the total number of States to 21. One state has left the program.

Table 25. Summary of objective #3 performance measures (continued).

PM #11: Number of State departments of transportation that subscribe to road weather products and services
• There has been a slight increase in the use of agency sensors (RWIS probes), private weather service providers, and information from the public (including through social media). • IMO sensors are now used by over half of the responding States. • There are fewer States using National Weather Service and Federal Aviation Administration products, the MADIS system, and agency field personnel for their weather and road weather information. Four (4) States now subscribe to USGS earthquake alerts versus zero from the previous period.
PM #12: Number of State departments of transportation collecting mobile observations of road weather data from appropriate vehicle fleets
• Overall, twenty-three (23) States, representing more than 50 percent of States surveyed, collect real-time field data from maintenance vehicles. This is an increase from 20 States in the 2015 survey. • Collecting plow status and material usage is most common, with thirteen (13) States reporting that they collect more than 50% of their data from maintenance vehicles. • Compared to the 2015 survey, there was an overall increase in the number of States reporting that they collect at least 25% of their real-time field data from plow status and material usage, atmospheric weather data (e.g. air temperature, relative humidity), and road weather conditions data (e.g. pavement temperature).
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 2,464 ESS, which continues the slight decrease seen in the previous update. • The majority of respondents use ESS data to provide current conditions to traveler information systems, to support decision-making, and as input to segment-level forecasts. However, while 70% of State DOTs use ESS data for traveler information systems, only 73% report using this data for decision-making, which is down from 95% in the previous period. • A positive change can be seen in the increase in the percentage of State DOTs that use ESS data to provide current road conditions to traveler information systems – from 60% in the 2015 survey to 70% in the 2017 survey.
ASOS – Automated Surface Observing System, AWOS – Automated Weather Observing System , DOT – department of transportation, ESS – environmental sensor station, IMO – Integrated Mobile Observations, 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.

Table 26. Summary of objective #4 performance measure.

PM #14: Number of/percentage of responding agencies using mobile data-based applications in road weather management
• Seven (7) States have developed applications or tools to use data generated by vehicle-to-infrastructure or infrastructure-to-vehicle connectivity. A further seventeen (17) States are considering developing such tools.
PM – performance measure

Objective 5: Advance the state of the practice by promoting tailored management strategies for different regions.

Table 27. Summary of objective #5 performance measures.

PM #15: Number of States disseminating weather advisory and other road weather information to travelers
• There is a significant increase in the use of dynamic messaging signs to show atmospheric weather and road condition information. • More agencies are using social media or mobile applications to disseminate information to travelers, as the use of these portals has increased much more than agency-hosted websites or 511 portals. • The use of highway advisory radio has dropped – only half as many States reported statewide dissemination of information over highway advisory radio compared to the previous period.
PM #16: Number of agencies using control and treatment strategies during weather events
• Traffic incident management continues to be the most widely deployed strategy, with 85% reporting partial or statewide deployment. • Loan/road closures and traffic diversions are much less common, showing an almost 30% decrease from the previous period. Temporary vehicle restrictions are also on the decline, as are variable speed limits. • Ramp meters are being used by 30% of the respondents, up from the previous period.
PM #17: Number of agencies that have participated in or conducted road weather management capability maturity assessment exercises
• Ten (10) States have conducted the capability maturity assessment workshops, and one more State has indicated interest. • Since the framework was recently developed in 2014, there was no participation to report in the previous period. It is promising that already 10 States, spanning a diverse range of climates, have participated in the in-person workshops in a short amount of time (2015-2017).

Table 27. Summary of objective #6 performance measures (continued).

PM #18: Number of agencies that coordinate with their local forecast offices for road weather management and operations
• Almost all respondents (98%) reported at least some coordination with the National Weather Service (NWS) local forecast office, with 55% saying they routinely coordinate and have access to meteorological expertise. This represents a large increase from 2015, where one-third of the respondents were just starting to work with the NWS.
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.

Table 28. 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 MDSS deployments, whether statewide or partial, has decreased. • There is a corresponding increase in the number of States saying that they do not need an MDSS, whereas the percentage of States saying they need one but do not have one has remained steady. This could suggest that those States that have tried using an MDSS have not found it useful, but that there is a perceived need for such a system. • In 2016, FHWA's Road Weather Management Program partnered with the South Dakota DOT to develop and implement a weather responsive traffic management (WRTM) strategy. 24-hour road condition forecasts transfer directly from South Dakota's Maintenance Decision Support System (MDSS) and to their traveler information systems as possible future "threats" when road conditions might deteriorate due to unsafe situations.
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.

Table 28. Summary of objective #6 performance measures (continued).

PM #21: Number of agencies reporting use of appropriate analysis tools to factor weather impacts and strategies
• Ninety five (95) percent of the respondents either did not use or were not aware of whether their agency used weather-responsive analysis tools and models, which is a substantial increase from the last update. • Of those who are using such tools, three (3) States are using sketch-planning analysis tools, and one State is using travel demand analysis and traffic signal optimization tools. • A 2016 Transportation Research Board study, speed and visibility data were analyzed at several locations along I-64 and I-77 in Virginia, where fog often developed. The research aimed to understand motorists' existing speed choices during low visibility. The models revealed that there is a significant differential between observed speeds and the desired safe speed.
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.

Table 29. 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
• There has been a decline in the number of State agencies participating in courses offered by the Consortium for ITS Training and Education (CITE), but this is expected since the number of RWM practitioners in transportation agencies remains fairly constant.
PM #23: Number of agencies and participants in road weather management webinars led by the Road Weather Management Program
• The number of agencies participating in RWMP Road Weather Regional Roundtables (webinars) is increasing.
PM #24: Number of meetings, site visits, or venues where road weather management presentations/briefings were made
• In the 2015-2017 timeframe, RWMP was represented by program staff or support contractors at more than 20 conferences, meetings, peer exchanges, etc.
PM #25: Number of hits/visits to RWMP website
• None available.
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 and sustainability communities.

Table 30. Summary of objective #8 performance measures.

PM #26: Number of public agencies meeting sustainability criteria related to road weather management
• Fewer DOTs than in the previous period reported developing and implementing sustainability criteria related to road weather management as identified by Infrastructure Voluntary Evaluation Sustainability Tool (INVEST).
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. • Half of all respondents have developed practices for responding to extreme weather, and approximately 20% reported conducting vulnerability/risk assessments, developing resiliency plans, and participating in State DOT resiliency adaptation planning activities. • Thirty-seven (37) percent expressed being uncertain about their State's activities related to climate change and extreme weather.
DOT – department of transportation, INVEST – Infrastructure Voluntary Evaluation Sustainability Tool, PM – performance measure

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