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2019

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, 2015, and 2017, and this update is the next iteration of this periodic review. This report provides a 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 2019 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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List of Acronyms

AASHTO	American Association of State Highway and Transportation Officials
AMS	Analysis, Modeling, and Simulation
APWA	American Public Works Association
ASOS	Automated Surface Observing Systems
AV	Autonomous Vehicle
AWOS	Automated Weather Observation System
CATT	Center for Advanced Transportation on Technology
CITE	Consortium for Innovative Transportation Education
CMF	Capability Maturity Framework
CMM	Capability Maturity Model
CSO	Committee on Transportation Systems Operations
CTDOT	Connecticut Department of Transportation
DOT	Department of Transportation
EDC	Every Day Counts
ESS	Environmental Sensor Stations
FARS	Fatality Analysis Reporting System
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
GIS	Geographic Information Systems
I2V	Infrastructure-to-vehicle
IMO	Integrated Mobile Observations
IMRCP	Integrated Modeling for Road Condition Prediction
ITS	Intelligent Transportation Systems
LTAP	Local Technical Assistance Program
MADIS	Meteorological Assimilation Data Ingest System
MDSS	Maintenance Decision Support System
MnDOT	Minnesota Department of Transportation
NOAA	National Oceanic and Atmospheric Administration
NHDOT	New Hampshire Department of Transportation
NHI	National Highway Institute

NHTSA	National Highway Traffic Safety Administration
NOAA	National Oceanic and Atmospheric Administration
NTCIP	National Transportation Communication for Intelligent Transportation Systems Protocol
NTOC	National Transportation Operations Coalition
NVDOT	Nevada Department of Transportation
NWS	National Weather Service
NYSDOT	New York State Department of Transportation
OFCM	Office of the Federal Coordinator for Meteorology
PCB	Professional Capacity Building
PIARC	World Road Association (formerly, Permanent International Association of Road Congresses)
PM	Performance Measure
R&D	Research and Development
ROI	Return on Investment
RWIS	Road Weather Information System
RWM	Road Weather Management
RWMP	Road Weather Management Program
RWM CMF	Road Weather Management Capability Maturity Framework
SaMS	Salt Management Strategies
SHA	State Highway Administration
TOPS-BC	Tools for Operations—Benefit Cost Analysis
TRB	Transportation Research Board
TSMO	Transportation Systems Maintenance and Operations
USGS	United States Geological Survey
V2I	Vehicle-to-Infrastructure
VDOT	Virginia Department of Transportation
VMT	Vehicle Miles Traveled
VSL	Variable Speed Limit
WRMS	Weather-Responsive Management Strategies
WRTM	Weather-Responsive Traffic Management
WSI	Winter Severity Index
WxDE	Weather Data Environment

Executive Summary

The Federal Highway Administration's (FHWA) Road Weather Management Program (RWMP), more than a decade ago, 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, 2015, and 2017. Over the years, the RWMP 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. For the 2019 report, two performance measures were removed from the assessment of RWMP objectives as they were deemed to measure outdated or irrelevant road weather management practices. As a result, 25 performance measures are evaluated in this *2019 Road Weather Management Performance Measures Update* . This update maintains the same performance measures to assess the RWMP's success in meeting its programmatic objectives:

1. Build and sustain relationships with multidisciplinary partners to expand road weather management deployments.
2. Ensure that road weather management investments improve highway performance.
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 management capabilities and awareness across the transportation and weather communities.
8. Increase engagement of the operations community with the weather resiliency and sustainability communities.

Assessing performance measures allows the RWMP to evaluate its progress, gather information on 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. It serves as a potential resource and communication product for advancing the importance and widespread implementation of road weather technologies.

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 an increasing number of agencies are collecting and reporting data on road weather performance measures, though many agencies still are determining the best methods for increasing capabilities for road weather management strategies and communicating those benefits to the public. Some examples are: 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.

Since the 2017 update, snow and ice removal expenditures have fluctuated based on the weather conditions but notable reductions in salt usage were not observed. Also, not many agencies are currently tracking the impact of road weather management on travel time reliability, but there are some notable practices for reducing delays in inclement weather. The Virginia Department of Transportation (VDOT), for example, implemented a variable speed limit in a corridor with frequent fog events to influence driver behavior. VDOT found that doing so did not significantly delay travel into or out of the corridor.

A primary concern for the RWMP and transportation agencies is reducing roadway fatalities. The rate of fatal crashes during inclement weather has remained relatively constant in the past 8 years.

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 Departments of Transportation (DOTs) using such systems since the previous report has remained relatively constant for most tools. However, fewer agencies reported relying on National Weather Service (NWS) products, and more reported relying on public or social media for information. The research team found that agencies increasingly are collecting real-time field data from their maintenance vehicle fleet, primarily for information on snowplow status and material usage.

The percentage of State DOTs using a Maintenance Decision Support System has increased, with more usage reported than the 2017 report. The RWMP encourages State DOTs to utilize road weather management strategies that best fit the local context. Fewer agencies are finding it helpful to provide traveler information to the public, but more are using weather-related decision support tools to support non-winter weather maintenance activities. Still, 83.8% of agencies reported that they did not use or were unaware if they used weather-responsive analysis, modeling, or simulation tools.

The research team also followed up on the 2017 update by tracking the use of vehicle-to-infrastructure or infrastructure-to-vehicle applications and connected vehicle technology. This topic has overwhelming improvements since the last update. Whereas in the previous update just 17% of agencies had developed an application that used real-time data from vehicle fleets, in this update, over 44% of agencies reported having developed an application. An additional 47% reported considering the development of one.

More agencies also reported that they had conducted a vulnerability assessment; developed or implemented a process for responding to extreme weather or a plan for resilient road weather management infrastructure; or participated in State DOT resilience adaptation planning

activities.

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 increased. A notable development since the last update, the RWMP has been converting the Consortium for Innovative Transportation Education's (CITE's) road weather management courses into a more broadly applicable format to be delivered by the National Highway Institute (NHI).

FHWA has worked with 16 State DOTs to conduct Road Weather Management Capability Maturity Framework (CMF) workshops. These workshops walk the agency through a self-assessment that was developed in 2014 to assess institutional road weather management capabilities and to help identify priority actions for increasing those capabilities.

PARTNERSHIPS AND STAKEHOLDER COLLABORATION

Because information sharing is fundamental to the implementation and success of road weather management strategies, FHWA and contractor staff frequently collaborate with public and private stakeholders through various activities on behalf of the RWMP. To gauge the effectiveness of these efforts, the RWMP tracks the numbers of State agencies advancing research and development projects, such as Pathfinder, Road Weather Management CMF, Weather Data Environment, and the Integrated Mobile Observations Program. In 2019, all major research and development (R&D) projects observed an increase in participation, and 43 States were involved in at least one project.

The RWMP also supports the National Oceanic and Atmospheric Administration (NOAA) and the National Weather Service (NWS) by encouraging State DOTs to utilize resources like NOAA's Meteorological Assimilation Data Ingest System (MADIS) or the National Weather Service's NWSchat. The research team found that fewer numbers of agencies rely on MADIS, but more agencies routinely coordinate with NWS to assist decision-making related to inclement weather or major events.

CONCLUSIONS

The RWMP is at a turning point with close to 15 years of research and development, stakeholder engagement, and accomplishments. Overall, the program's role in enabling improved management of the transportation system during adverse weather is evident in the strong growth in use of tools, programs, and activities by State DOTs. The results from the performance measurement show the sustained interest and growth in Every Day Counts (EDC)-supported strategies. As EDC-4 and EDC-5 ramp down, the question becomes: What are the next steps for the program in terms of supporting the advancement of road weather management practices? The 2019 performance measurement data provides some clues about likely needs and requirements for the program, such as:

- Need for more case studies on material management practices, especially documenting State DOT approaches to optimizing usage of salt.

- Need to re-engage State DOTs on Road Weather Information System (RWIS) data sharing. This update revealed that a smaller number of State DOTs are reporting their contributions to MADIS. The role of RWIS data sharing may re-emerge as a priority, especially with other voluntary data exchanges being developed to support automated driving systems.
- Overall, there is significant growth in the use of data generated from vehicle platforms for road weather maintenance. Maintaining these advancements requires the RWMP to support overall maturity in the use of these systems, including data management practices, application development, and the systems' operations and maintenance.
- A map of survey respondents and analysis of State involvement reveal clear geographical gaps in engagement in the southeastern United States. This may result from the markedly different focus on winter weather-related activities historically by the program as well as the Southeast. Understanding the needs of these States and seeking to engage them more would make the program more broad-based in terms of looking at road weather impacts beyond snow and ice control. The Pathfinder initiative is currently evolving to be more inclusive of non-winter events, such as flooding, tropical storms, and dust storms.

Chapter 1. Introduction

Since 2006, the Federal Highway Administration's (FHWA's) 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 the program performance were conducted and documented in 2009,[1] 2012,[2] 2015,[3] and 2017.[4] These updates reviewed program initiatives and major accomplishments; assessed the continued suitability, strengths, and weaknesses of existing measures for evaluation program performance; and incorporated new measures, as appropriate, that reflected current and future program initiatives. The *2019 Road Weather Management Performance Measures Update* is a continuation of this periodic review of the RWMP's performance and an update to the 2017 report.

OBJECTIVES OF THE 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 United States' overall capability with respect to road weather management. The report also serves as a resource and outreach product to advance the importance and widespread implementation of road weather technologies. This assessment helps communicate the overall success of the RWMP and identify areas that need more focus, support, or outreach. The 2019 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 multidisciplinary partners to expand road weather management deployments.
2. Ensure road weather management investments improve highway performance.

[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.

[4] Federal Highway Administration, 2017 Road Weather Management Performance Measures Update. FHWA-HOP-17-048, October 2017. Available at: https://ops.fhwa.dot.gov/publications/fhwahop17048/index.htm.

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 management capabilities and awareness across the transportation and weather communities.
8. Increase engagement of the operations community with the weather resiliency and sustainability communities.

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

- ***Every Day Counts (EDC-5) Initiative—Weather-Responsive Management Strategies (WRMS).*** The strategies focus on using mobile and connected vehicle data from traffic and maintenance management during weather events. Building from the EDC-4 Weather Savvy Roads innovation, FHWA is assisting agencies in the implementation of various activities and products.
- ***Road Weather Management Capability Maturity Framework (RWM CMF) Workshops.*** The RWMP has conducted a total of 16 RWM CMF workshops in 15 States. These workshops help agencies evaluate their current capabilities in managing the transportation system during road weather events and assist in creating a roadmap of prioritized actions for increasing capabilities across the six sectors of the CMF.
- ***National Highway Institute (NHI) Road Weather Management Courses.*** The RWMP is updating and converting the road weather management Consortium for ITSTraining and Education (CITE) courses into a format to be delivered by the National Highway Institute. The Road Weather Information System (RWIS) Equipment and Operations course is available in the Institute catalogue and is free to the public.
- ***Weather-Responsive Traffic Management (WRTM) Implementation Projects.*** The RWMP worked with the Delaware DOT and Washington State DOT to evaluate the *Guidelines for Deploying Connected Vehicle-Enabled Weather Responsive Traffic Management Strategies*.

RESEARCH APPROACH

The research team's approach for the 2019 update included a review of the 2017 update, as well as the program's current objectives, activities, and products. The team then developed a plan for conducting the 2019 update and provided recommendations for presenting the results. In general, the reporting period for the performance updated is from January 2017 to mid-year 2019. These categories of sources provided data elements for the performance measures:

- ***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 RWMP activities.
- ***State Department of Transportation (DOT) Survey.*** A targeted survey of State DOTs provided data on the current practices and capabilities for road weather management around the country. The survey was completed by 39 State DOTs, which is one State less than responded to the 2015 and 2017 updates. Figure 1 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, and 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 measure update. In many cases, these data elements are used to support the findings for the performance measures.

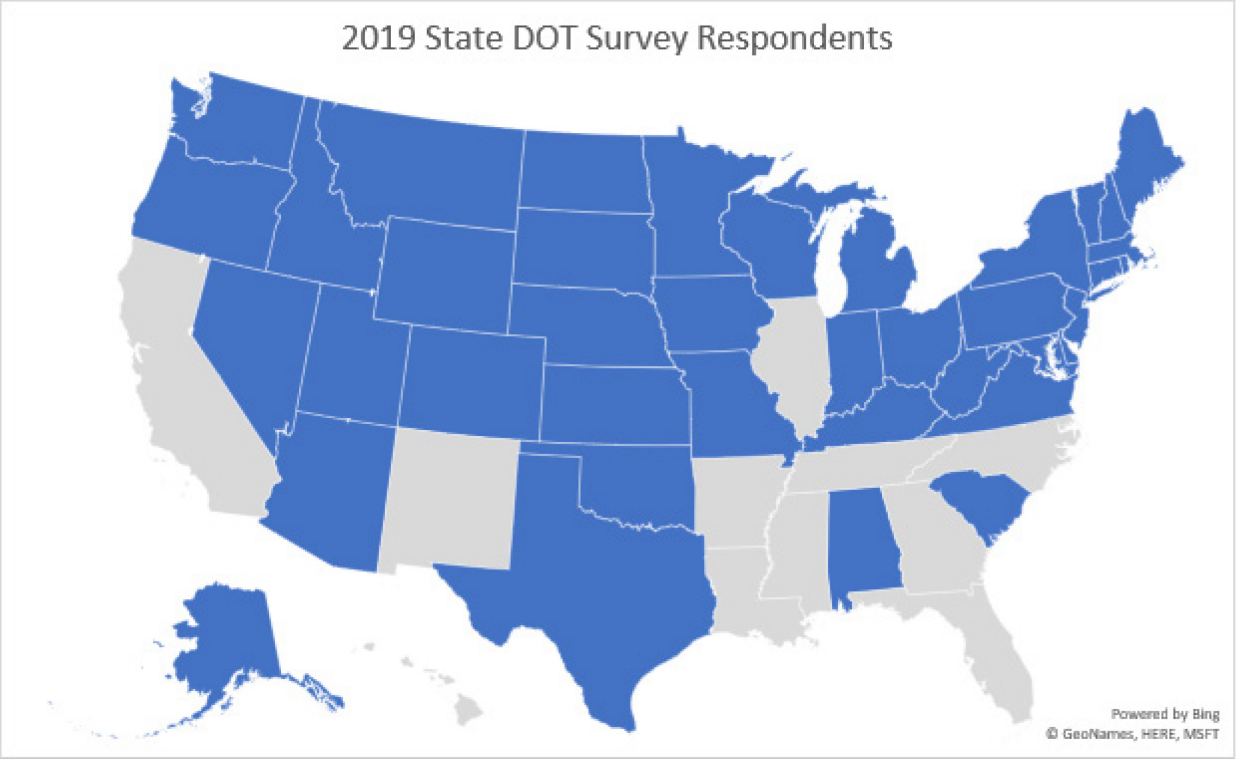


Figure 1. Map. States that responded to the 2019 Road Weather Management State DOT Survey

For this update, the research team designated each performance measure as an output (direct effort of RWMP), an outcome (response from transportation agencies and other stakeholders), or an impact (changes in transportation system performance including user, agency and societal costs and benefits). After designating each performance measure, the team identified data

sources, related activities, and the strengths and weaknesses of each measure. By looking beyond each measure's latest result and analyzing the components that factored into the result, the research team was able to take a more holistic look at the RWMP's progress and successes. Table 1 summarizes the 25 performance measures in this way.

Table 1. Data Sources, Related Activities, and Strengths and Weaknesses of Each Performance Measure

PM #	RWMP Performance Measure	Type of Measure	Primary Data Source	Related Activities in 2017-2019 That May Influence the Measure	Link to Activities	Measure Strengths (S) & Weaknesses (W)
Objective 1: Build and sustain relationships with multidisciplinary partners to expand road weather management (RWM) deployments.						
1	Number of agencies participating in road weather R&D projects	Output	FHWA RWMP (interviews with staff and review of R&D program)	• EDC-4 • EDC-5 • Weather Data Environment • Weather-Responsive Traffic Management (WRTM) implementation support activities	High	S: Clearly illustrates the collaborative nature of RWMP R&D. W: The quantification of the measure is very sensitive to how "participation" is defined.
2	Number of agencies participating in and benefiting from RWMP stakeholder meetings/ workshops	Output	RWMP records	• RWM stakeholder meetings, 2017 and 2018 • RWM CMF Workshops, 2017 and 2018 • WRTM stakeholder meetings, 2017 • EDC-4 Weather Savvy Roads Innovation • EDC-5 Weather Responsive Traffic and Maintenance Management Innovation	High	S: Illustrate the diversity of agencies participating in RWM workshops; workshop participants benefit from the peer-to-peer interaction and additional training. W: While feedback on the workshops is uniformly positive, it is unclear how to quantify the benefits of the workshop to the participants.
Objective 2: Ensure that road weather management investments improve highway performance.						
3	Number of agencies that collect and report road weather-related performance measures to the public (i.e., winter severity index, mobility index)	Outcome	State DOT Survey as well as internet research	All activities can support this measure, but direct attribution of specific activity is difficult	High	S: Shows the improvement in agency transparency on RWM efforts. W: Lack of widely accepted standards for measuring success of snow and ice control activities.

PM #	RWMP Performance Measure	Type of Measure	Primary Data Source	Related Activities in 2017-2019 That May Influence the Measure	Link to Activities	Measure Strengths (S) & Weaknesses (W)
4	Number of agencies that have a process for evaluating the return on investment (ROI) or net benefit of their RWM investments	Outcome	State DOT Survey	Compendium and technical briefs on benefit-cost analysis for road weather management	Medium	S: Shows agency engagement in gauging its own performance for continuous improvement.
5	Reductions in agency costs of weather-related maintenance and operations activities	Impact	Highway Statistics publication series and internet research for case studies	All activities can support this measure, but direct attribution of specific activity is difficult	Medium	S: With States' budget constraints, case studies and data showing potential cost savings may encourage more States to implement road weather strategies. W: While individual case studies and national trends are available, linkage to program activities is difficult.
6	Reduction in number and types of fatalities and crashes attributed to adverse weather, nationally	Impact	FARS, NHTSA databases and internet research for case studies	All activities can support this measure, but direct attribution of specific activity is difficult	High	S: With road weather as part of the EDC initiative, case studies and safety effects of road weather strategies are important to show. W: While individual case studies and national trends are available, linkage to program activities is difficult.
7	Reductions in extent of capacity losses and delays due to fog, snow, and ice events, including freight	Impact	Internet research, Case studies	All activities can support this measure, but direct attribution of specific activity is difficult	High	W: No clear national-level dataset on this topic. Localized case studies serve as a surrogate approach.
8	Increase in travel time reliability or decrease in variability due to road weather management strategies during adverse weather scenarios	Impact	Internet research, Case studies	All activities can support this measure, but direct attribution of specific activity is difficult	High	W: No clear national-level dataset on this topic. Localized case studies serve as a surrogate approach.

PM #	RWMP Performance Measure	Type of Measure	Primary Data Source	Related Activities in 2017-2019 That May Influence the Measure	Link to Activities	Measure Strengths (S) & Weaknesses (W)
9	Reduction in tons of salt or chemical usage in the U.S. normalized by winter severity index	Impact	United States Geological Survey Minerals Yearbook: Salt (2006-2015) and internet research, Salt Institute, and AASHTO Standing Committee on Maintenance	All activities can support this measure, but direct attribution of specific activity is difficult	High	W: While individual case studies and national trends are available, linkage to program activities is difficult. The lack of a common winter severity index makes temporal comparisons difficult.
Objective 3: Transportation, weather, and research communities use and rely on fixed and mobile road weather observations.						
10	Number of State DOTs participating in MADIS program	Outcome	NWS and RWMP records	• Support *Clarus* transition to MADIS • Data sharing agreements support	High	S: Directly shows if the broad national scope of *Clarus* transitioned to State implementation of MADIS. W: MADIS system is currently still in development stages with NOAA. Hence usage is still limited by DOTs
11	Number of State DOTs that subscribe to road weather products and services	Outcome	ITS Deployment Statistics and State DOT Survey	• Road Weather CMFs • Pathfinder • Integrated Mobile Observations (IMO)	High	S: Directly shows growth in agency use of weather and road weather information.
12	Number of State DOTs collecting mobile observations of road weather data from vehicle fleets	Outcome	State DOT Survey	• IMO program • Standards support (connected vehicles, NTCIP 1204, J2735 SE)	High	S: Directly shows growth in agency use of mobile data for road weather. Also identifies the type of data that are collected from maintenance vehicles, as well as from what percentage of the applicable fleets. W: Use of mobile data standards is still in its infancy

PM #	RWMP Performance Measure	Type of Measure	Primary Data Source	Related Activities in 2017-2019 That May Influence the Measure	Link to Activities	Measure Strengths (S) & Weaknesses (W)
13	Number of State DOTs reporting the use of Environmental Sensor Stations (ESS) in operations and maintenance activities	Outcome	FHWA's RWMP records, ITS Deployment Statistics, State DOT Survey, Aurora Pooled Fund program	• IMO – how permanent and transportable ESS data are enhanced by mobile ESS • IMRCP – how permanent ESS data are used in modeling the effects of weather of on the roads • WxDE – how quality checked ESS data enhances the correct usage of data	Medium	S: Directly shows and tracks the usage of ESS to support management and maintenance decision-making.
Objective 4: Advance the state of the art for mobile-sensing and integrating vehicle data into road weather applications.						
14	Number of/percentage of responding agencies using mobile data-based applications in road weather management	Outcome	RWMP records and State DOT Survey	• IMO program • EDC-5 WRMS Program	High	S: Directly shows growth in agencies' use of mobile data-based applications for RWM and growth in their partnership with new groups involved in RWM with such applications.
Objective 5: Advance the state of the practice by promoting tailored management strategies for different regions.						
15	Number of States disseminating advisory weather and road weather information to travelers	Outcome	ITS Deployment Statistics, State DOT Survey, State statistics	• EDC-4 Pathfinder initiative • EDC-5 WRTM implementation support activities • Messaging guidelines for road weather	High	S: Direct measure to assess adoption of road weather messaging around the country
16	Number of agencies using control and treatment strategies during weather events	Outcome	ITS Deployment Statistics and State DOT Survey	• EDC-4 Pathfinder initiative • EDC-5 WRTM implementation support activities	Medium	S: Direct measure to assess adoption of road weather control around the country. W: Diversity of strategies and application scenarios make this measure difficult to quantify effectively.
17	Number of agencies that coordinate with their local forecast offices for road weather management and operations	Outcome	State DOT Survey	• Pathfinder Initiative • Road Weather CMF	High	S: Reflects agency's commitment to enhancing the performance of road weather management and operations activities.
Objective 6: Weather-related decision support technologies are integrated into traffic operations and maintenance procedures.						

PM #	RWMP Performance Measure	Type of Measure	Primary Data Source	Related Activities in 2017-2019 That May Influence the Measure	Link to Activities	Measure Strengths (S) & Weaknesses (W)
18	Number of agencies adopting MDSS technologies and methods	Outcome	State DOT Survey and MDSS Pooled Fund program	• RWM Stakeholder Meeting	Low. No recent activities relating to MDSS	S: Directly shows growth towards advanced approaches to managing maintenance decisions and operations during inclement weather.
19	Number of agencies using other weather-related decision support tools	Outcome	State DOT Survey	• IMRCP Phase 2 and 3 • Tools for Operations Benefit Cost Analysis • AMS for RW-CV applications • WxDE	High	S: Directly shows growth in agency use of decision support tools in road weather.
20	Number of agencies reporting use of appropriate analysis tools to factor weather impacts and strategies	Outcome	State DOT Survey	• AMS for RW-CV applications • IMRCP	Medium	S: Directly shows growth in agency use of analysis, modeling, and simulation tools in road weather. W: Limited program activity in this area makes it difficult to attribute changes to program.
Objective: 7 Advance the state of the practice by raising road weather capabilities and awareness across the transportation and weather communities.						
21	Number of agencies and attendees who have taken any of the sponsored RWMP training courses and workshops	Output	FHWA RWMP records (for CMF workshops) and attendance records from CITE, University of Maryland	• RWM CMF workshops • CITE training courses	High	S: Directly illustrates the popularity and demand for RWMP training products.
22	Number of agencies and participants in RWM webinars led by the RWMP	Output	FHWA RWMP records and records from the ITS Professional Capacity Building (PCB) Program and other webinar sponsors/venues	• RWMP webinars • National Transportation Operations Coalition, T3, and Talking Freight webinars	High	S: Directly illustrates the popularity and demand for RWMP outreach topics.
23	Number of agencies that have participated in or conducted RWM capability maturity assessment exercises	Outcome	RWMP records	• RWM CMF • AASHTO Capability Maturity Model	High	S: Shows growth in agency use of capability maturity assessment tools and commitment to establish RWM as a core function.

PM #	RWMP Performance Measure	Type of Measure	Primary Data Source	Related Activities in 2017-2019 That May Influence the Measure	Link to Activities	Measure Strengths (S) & Weaknesses (W)
24	Number of meetings, site visits, or venues where RWM presentations/ briefings were made	Output	FHWA RWMP records	• RWMP partnership activities with partners such as pooled funds, TRB, ITS America, AASHTO, NWS, NOAA, Office of the Federal Coordinator for Meteorology, World Road Association-PIARC • National Dialogues on Highway Automation	High	S: Indicates the reach of the technical transfer activities undertaken by the program. W: It is difficult to correlate program success using the number of meetings staff are present at. A large conference with many attendees may present general information to a broader audience, while a smaller site visit may cover information more relevant to a specific agency.
Objective 8: Operations community is engaged with weather resiliency and sustainability communities.						
25	Number of agencies conducting vulnerability/risk assessment or developing/ implementing resiliency plans for their RWM infrastructure and processes to respond to extreme weather	Outcome	State DOT Survey	• FHWA Extreme Weather Adaptation activities	High	S: Shows the growth in agency awareness for weather resiliency, in managing extreme weather and improving the resiliency of operations. W: 2017 results indicate this is still an emerging area but limited activities have taken place within the program supporting this measure.

PERFORMANCE MEASURE MAPPING

For this report, each of the 25 performance measures are grouped into one of four 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

By associating performance measures with one or more of these categories, the RWMP goes

beyond simply listing each performance measure result and can anecdotally cover the successes of the program. Table 2 maps each performance measure to the appropriate categories. For a detailed analysis of findings by performance measure, see Appendix B: Findings by Measure.

Table 2. Performance Measure Mapping

PM #	RWM Impacts Assessment	Application of RWM Tools & Technologies	RWM Capacity Building	Partnerships & Stakeholder Collaboration
1. Number of agencies participating in road weather R&D projects			X	X
2. Number of agencies participating in and benefiting from RWMP stakeholder meetings/workshops			X	X
3. Number of agencies that collect and report road weather-related performance measures to the public (i.e., winter severity index, mobility index)	X			
4. Number of agencies that have a process for evaluating the return on investment (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 road weather management strategies during adverse weather scenarios	X			
9. Reduction in tons of salt or chemical usage in the U.S. normalized by winter severity index	X			
10. Number of State DOTs participating in MADIS program		X		X
11. Number of State DOTs that subscribe to road weather 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 Environmental Sensor Stations (ESS) in operations and maintenance activities		X		

PM #	RWM Impacts Assessment	Application of RWM Tools & Technologies	RWM Capacity Building	Partnerships & Stakeholder Collaboration
14. Number of/percentage of responding agencies using mobile data-based applications in road weather management		X		
15. Number of States disseminating advisory weather and road weather information to travelers			X	
16. Number of agencies using control and treatment strategies during weather events			X	
17. Number of agencies that coordinate with their local forecast offices for road weather management and operations			X	
18. Number of agencies adopting MDSS technologies and methods		X		
19. Number of agencies using other weather-related decision support tools		X		
20. Number of agencies reporting use of appropriate analysis tools to factor weather impacts and strategies		X		
21. Number of agencies and attendees who have taken any of the sponsored RWMP training courses and workshops			X	
22. Number of agencies and participants in RWM webinars led by the RWMP			X	X
23. Number of agencies that have participated in or conducted RWM capability maturity assessment exercises			X	
24. Number of meetings, site visits, or venues where RWM presentations/ briefings were made			X	X
25. Number of agencies conducting vulnerability / risk assessment or developing / implementing resiliency plans for their RWM infrastructure and processes to respond to extreme weather		X	X	

ORGANIZATION OF THE REPORT

This report is organized so that each chapter can stand alone. Each chapter covers one of the four categories described in the previous section.

- Chapter 2. Road Weather Management Impacts Assessment, describes the recent findings related to mitigating the mobility, safety, productivity, and 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 that 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 takeaways from the 2019 update and recommendations for the RWMP and its next performance measure update.

The report also includes two appendices:

- Appendix A: State Department of Transportation Survey lists the State DOT survey questions and response summary.
- Appendix B: Findings by Measure presents the findings for each performance measure in a concise tabular format.

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 strategies. The Federal Highway Administration's (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 related 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 activity and road weather impacts is not possible. However, overall trends provide a snapshot of the scope of the problems 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) are continually advancing their awareness and understanding of their transportation system's performance, as well as the direct outcomes from DOT intervention in managing the impacts weather events have on the system. State DOTs are still determining the best methods for collecting road weather performance data (e.g., dashboards, winter maintenance reports, and seasonal summaries) and reporting road weather performance metrics to the public. However, more State DOTs report collecting and reporting data about road weather performance (see Figure 2).

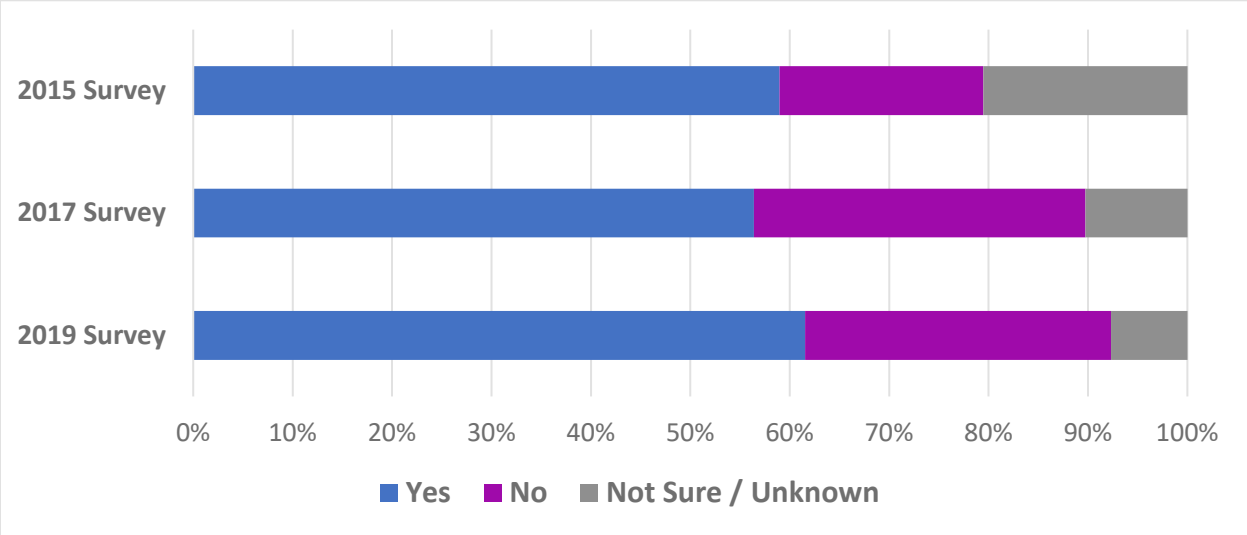


Figure 2. Graph. Percentage of agencies that collect and report road weather performance measures

After a brief dip in 2017, 61.5% of agencies (24 of 39 responding) reported collecting and reporting road weather management performance data in 2019. This is a net increase of two agencies from previously. Of note, the percentage of survey respondents who did not know or were unaware if their agency collected or reported this data has followed the downward trend observed during the previous update. The RWMP should continue to support the development of a consistent set of road weather performance measures to enable consistent assessment of impacts across the United States.

The 2017 update was the first time survey respondents indicated whether or not their agency used a "winter severity index" to compare system performance across events or years. The 2019 update repeated this question, and a small but distinguishably higher percentage of participants answered in the affirmative (see Figure 3). The change in percentage growth correlates to an additional two agencies reporting use of a winter severity index. There is a similar downward trend in the number of respondents who reported their agency as not having a winter severity index. This could also be explained by the increase in the number of answers that were marked as uncertain.

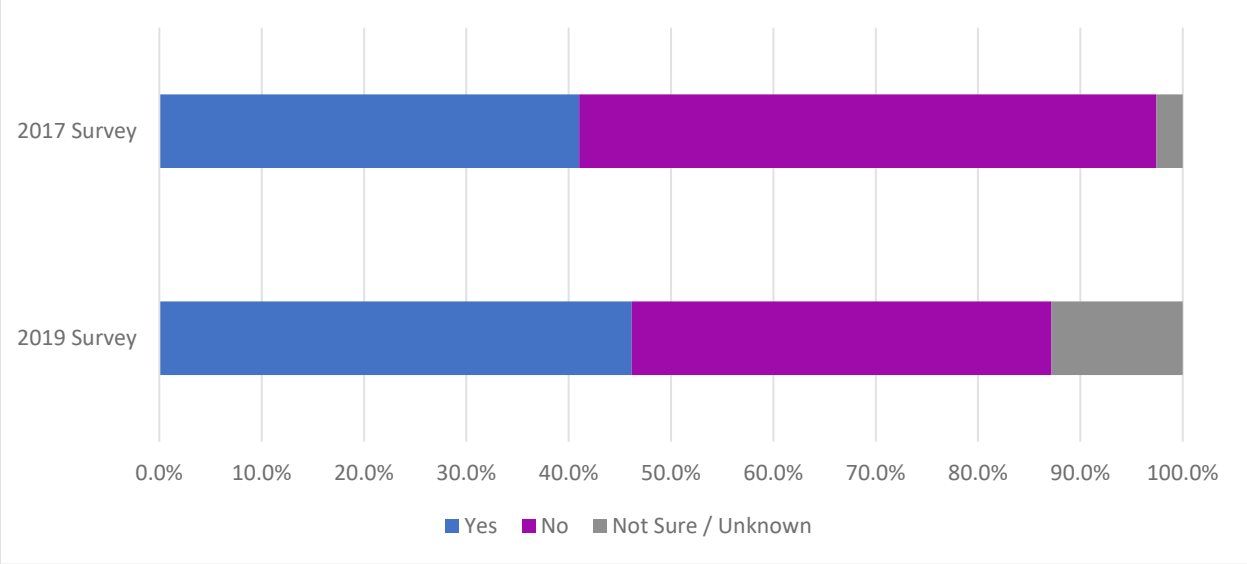


Figure 3. Graph. Percentage of agencies surveyed that use a "winter severity index" to compare performance across events or years

As shown in Figure 4, fewer State DOTs report having a process to evaluate the return on investment or net benefits of road weather management investments. Four State DOTs confirmed an established process, which is closer to the 2015 survey response of five agencies than the 2017 survey response of nine agencies. While this may be a function of different respondents to the surveys, there is an opportunity to look at the use of performance measures in greater depth by the RWMP as part of their technical support activities.

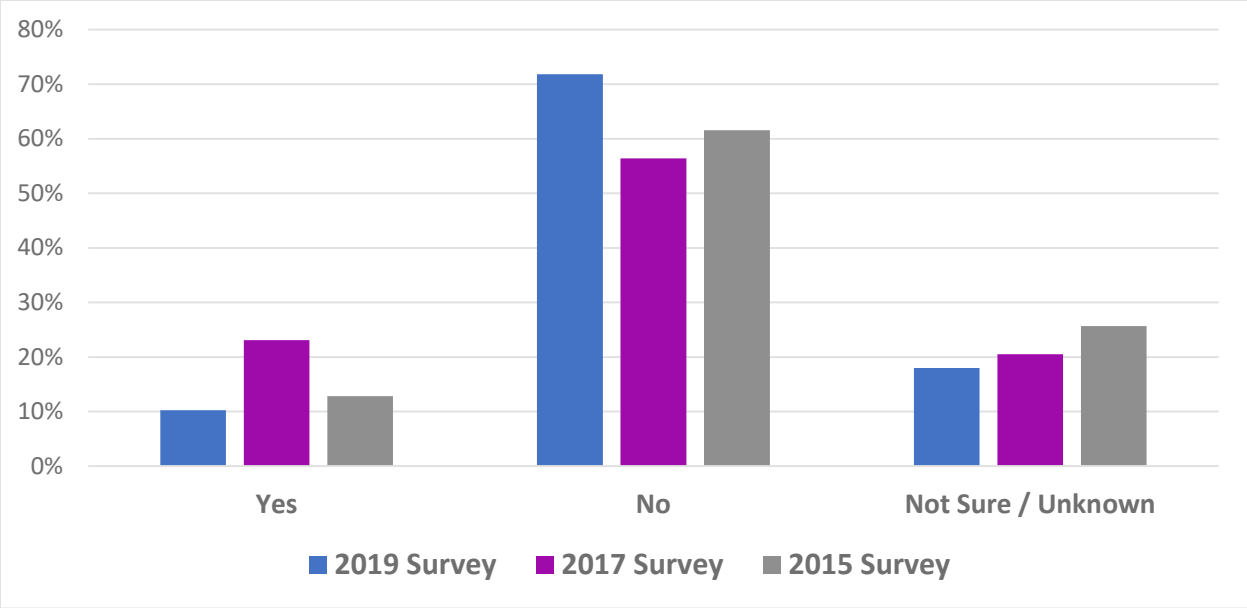


Figure 4. Graph. Percentage of agencies surveyed with a process for evaluating the return on investment or net benefit of their road weather management investments

National Trends in Road Weather Impacts

Road Salt Use and Cost

The research team studied two performance measures to assess the economic impacts State DOTs face through road weather operations and maintenance. The two factors studied for the report were total salt usage and total expenditures for snow/ice removal.

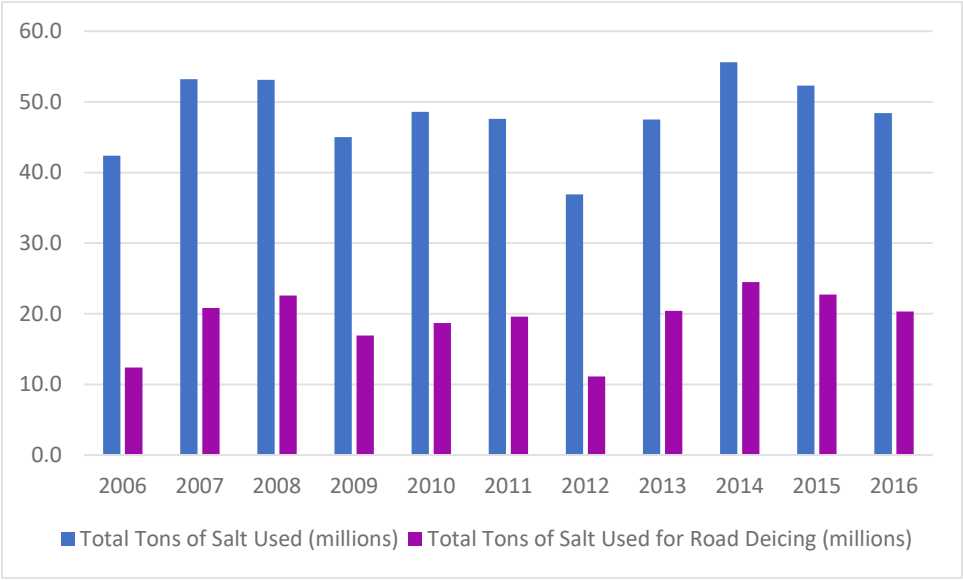


Figure 5. Graph. Nationwide salt usage by year (in millions of tons of salt)

Figure 5 summarizes the most recently available data on nationwide salt usage, including the proportion of salt utilized for road deicing. Roadway deicing accounted for 43.4% of total salt

usage in 2015 and 41.9% of total salt usage in 2016. These 2 years showed moderate decreases in the use of salt for roadway deicing (7.3% less in 2015 and 10.6% less in 2016).

The research team did not identify any new case studies on new or innovative road weather management strategies reducing salt usage.

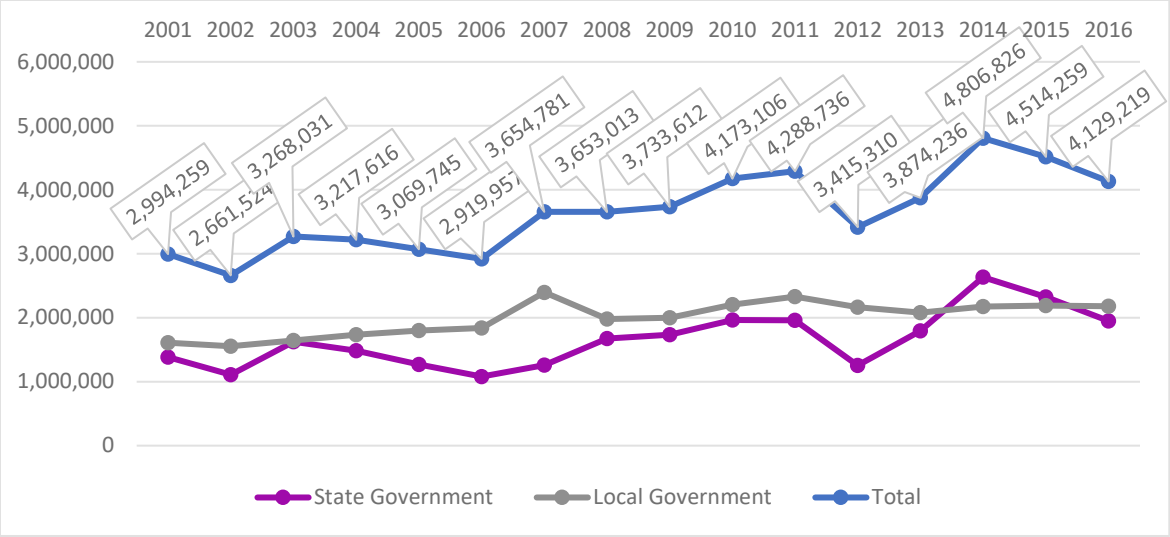


Figure 6. Graph. National expenditures for snow and ice removal, 2001-2016 (in thousands of dollars)

Figure 6 summarizes the most recently available data from the FHWA Highway Statistics Manual detailing national expenditures for snow and ice removal (in thousands of dollars) between 2001 and 2016.[5]

Local government expenditures for snow and ice removal have been relatively constant over the past 5 years, while State government expenditures were more variable. The 2017 update reported a 13% increase between 2012 and 2013. This upward trend continued in 2013 and 2014, when State governments saw a 46.7% spike in expenditures on snow and ice removal, bringing annual State government expenditures over local government expenditures for the first time since the RWMP has tracked the data.

In the 2 years after 2014, State government expenditures on snow and ice removal decreased by 16.0% and 8.5%, bringing State government expenditures back below local government expenditures in 2016. Due to the relative consistency of local government expenditures, the national trend on spending follows the State trend for the past 5 years.

These observations demonstrate the natural, unpredictable variation in weather and road weather conditions over a short period. A majority of States saw expenditures increase in 2014, but the

[5] Data Source: Highway Statistics (2001-2016) Data Tables SF-4C (Disbursements for State-Administered Highways) and LGF-2 (Local Government Disbursements for Highways). Available at: https://www.fhwa.dot.gov/policyinformation/statistics.cfm

most significant increases were in Arkansas, Delaware, Georgia, Louisiana, Maryland, Mississippi, Missouri, North Carolina, Oklahoma, South Carolina, and Texas.

Capacity Losses and Travel Time Reliability

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 the RWMP. Since the last performance measure update, the research team identified one additional delay-reducing strategy, which also has an overlap in safety goals.

- Virginia DOT implemented a variable speed limit system to combat reduced visibility associated with fog events on the I-77 corridor in Fancy Gap by reducing travel speeds on the corridor when fog was present. Prior to the installation, driver speeds remained relatively constant with non-fog conditions. After the installation, Virginia DOT found that drivers were willing to reduce speeds to the posted level, and that the reduction in speed within the corridor did not have a significant impact on travel into or out of the corridor.[6]

Not many, if any, agencies currently track the impact of road weather management on travel time reliability. Because both road weather management and travel time reliability are influenced by a multitude of factors, it is difficult to identify a specific action that has influenced the performance outcome.

Safety

As with all transportation challenges, it is crucial to measure safety impacts of managing adverse weather. The RWMP monitors the total number of fatal crashes, including the total number occurring during inclement weather. Because the total number of licensed drivers increases on an annual basis, the RWMP indexes the number of fatalities each year by looking at the crash rates per licensed drivers and per vehicle miles traveled (VMT). This standardizes the safety metrics on a year-to-year basis, which allows for more meaningful comparison.

[6] Gonzales D, Fontaine M (2018) Impact of a Variable Speed Limit System on Driver Speeds During Low Visibility Conditions. Available at: https://pubsindex.trb.org/view/2018/C/1495670

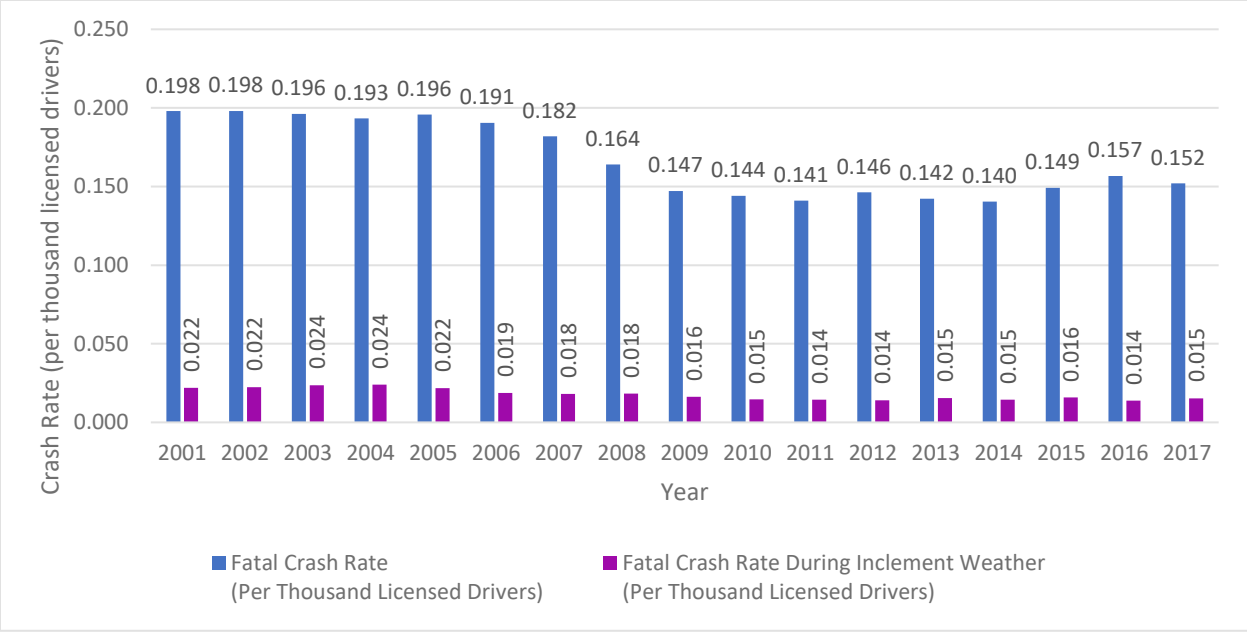


Figure 7. Graph. Fatal crash rates per thousand licensed drivers, 2001-2017

Fatal crash data from 2017 is the most recently available at the time of this report.[7] The prior update covered through 2014. Figure 7 shows the total fatal crash rate per thousand licensed drivers, including the breakout of how many fatal crashes occurred during inclement weather. The fatal crash rate during inclement weather per thousand licensed drivers peaked in 2003-2004 at 0.024 crashes per thousand licensed drivers. That rate has steadily decreased to between 0.014 and 0.016 crashes per thousand licensed drivers for 2009-2017.[8]

[7] Data source: National Highway Traffic Safety Administration, Fatality Analysis Reporting System Encyclopedia. Available at: https://www-fars.nhtsa.dot.gov/Crashes/CrashesTime.aspx

[8] Note: The weather conditions for many crashes in 2016 (1,700 crashes) and in 2017 (2,547 crashes) are unknown. NHTSA refines past data as more information becomes available, so it is possible that the fatal crash rates will rise above the 0.016 threshold for these years.

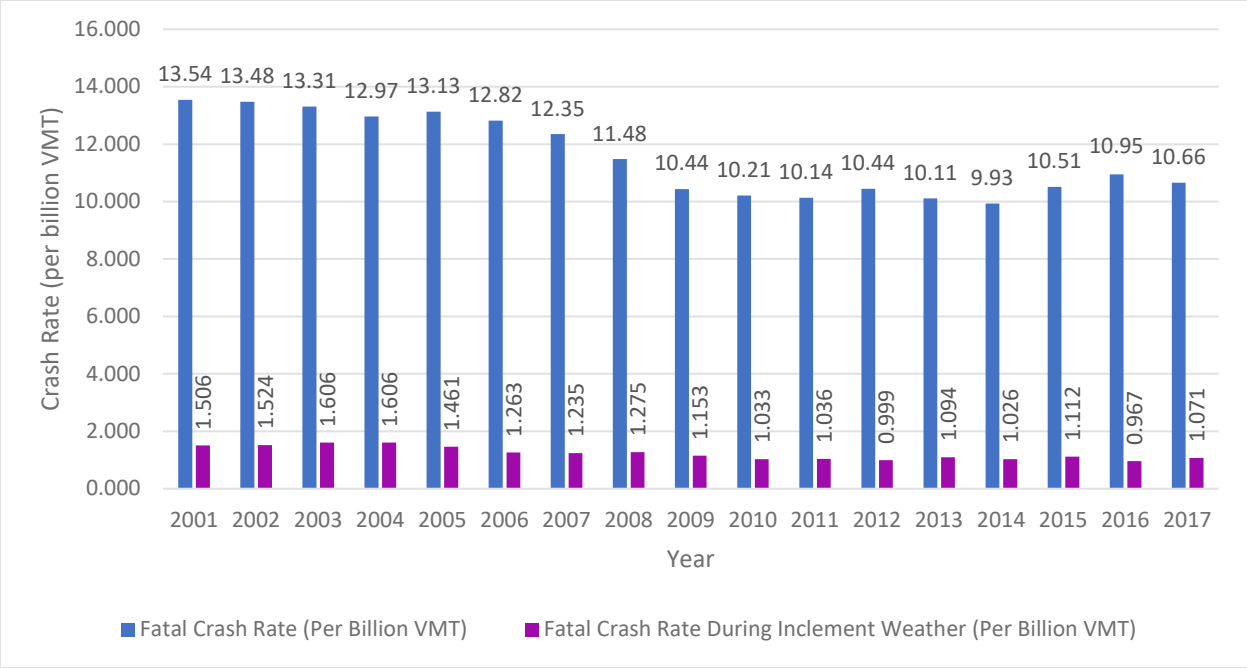


Figure 8. Graph. Fatal crash rates per billion vehicle miles traveled, 2001-2017

When indexing to vehicle miles traveled (VMT) instead of licensed drivers, a similar trend emerges. The VMT index (Figure 8) follows a similar pattern to the patterns of licensed drivers in Figure 7. Both figures illustrate how the crash rate has decreased from 2001-2010 and then grew slowly since 2010. The rate of fatal crashes occurring during inclement weather follows the same trend, but is less distinguishable than the total crash rate.

The RWMP maintains 10-year averages on weather-related crash statistics, and shows that a majority of incidents occur due to wet pavement:[9]

- 70% of weather-related crashes occur on wet pavement.
- 46% of weather-related crashes occur in rain.
- 18% of weather-related crashes occur in snow or sleet.
- 13% of weather-related crashes occur on icy pavement.
- 16% of weather-related crashes occur on snowy or slushy pavement.
- 3% of weather-related crashes occur in foggy conditions.

The fact that the trend for fatal accidents during inclement weather mirrors the trend for total fatal accidents suggests that the observed decrease in fatalities during inclement weather is most likely a product of decreased fatalities overall. There is not enough evidence to suggest that weather-related fatal crashes decreased independently as a result of specific road weather management strategies.

[9] FHWA Office of Operations Road Weather Management Program, "How Do Weather Events Impact Roads?" Accessed September 5, 2017. Available at: http://www.ops.fhwa.dot.gov/weather/q1_roadimpact.htm

Chapter 3. Application of Road Weather Management Tools and Technologies

OVERVIEW

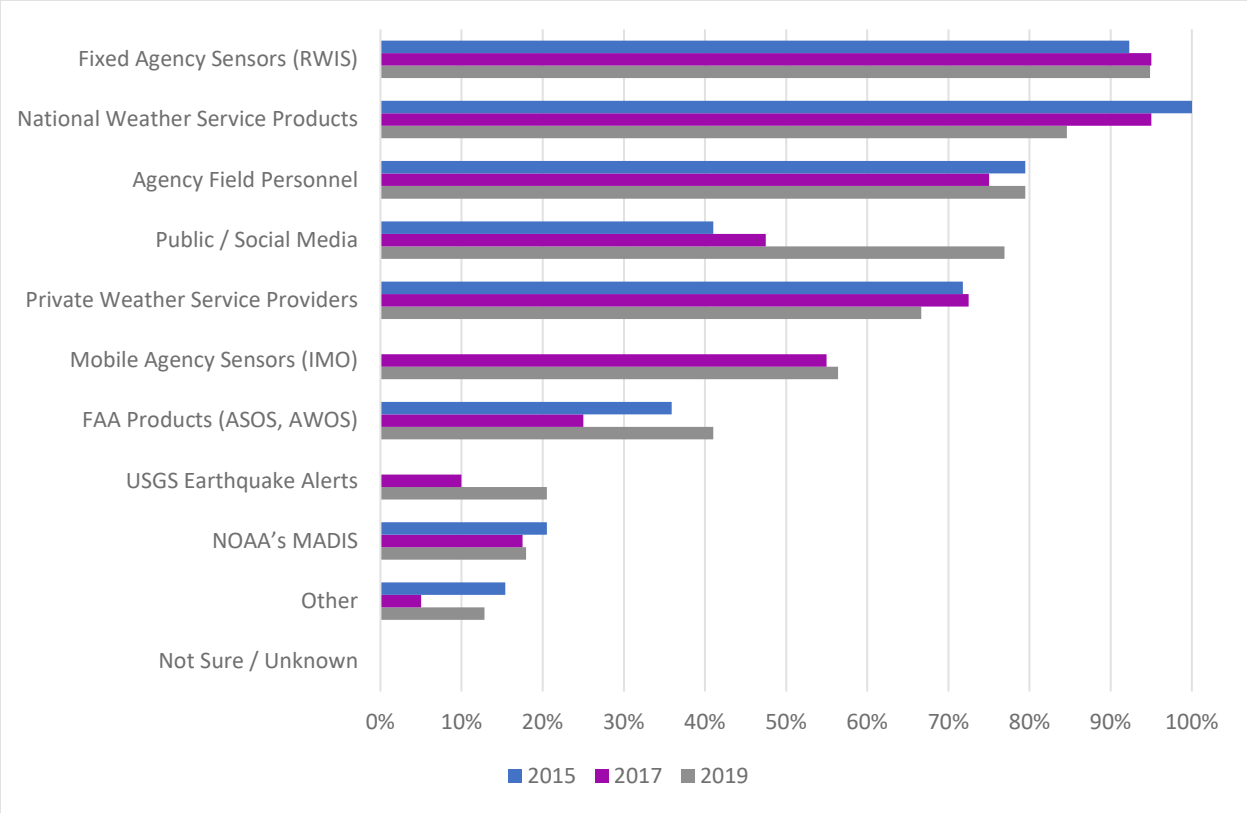
This section focuses on the specific tools and technologies used by agencies for road weather management, including the number of State departments of transportation (DOTs) that have adopted them to date.

PERFORMANCE FINDINGS

Use of Fixed and Mobile Observations

The first set of road weather management 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 to review State DOTs' subscription rates and use of observational data—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.

Through the 2019 State DOT survey, respondents reported lower participation in the National Oceanic and Atmospheric Administration's (NOAA's) Meteorological Assimilation Data Ingest System (MADIS). MADIS offers robust quality-checked data that are available to support traffic management, inform maintenance-related decision-making and performance measurements, and provide information on current conditions to the traveling public at a national level. As of 2019, the number of States reporting involvement in MADIS dropped from 21 to 13.



ASOS = Automated Surface Observing Systems. 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 = U.S. Geological Survey

Figure 9. Graph. Percentage of States that subscribe to weather and road weather products and services

State DOTs reported high levels of subscriptions 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. Information on the percentage of States that subscribe to various sources of road weather products and services is available in Figure 9.

Since 2017, the number of subscribers of these services has remained relatively constant. However, there are a few notable differences in this update. Significantly more State DOTs reported utilizing data from public and social media than in prior updates. Fewer State DOTs reported utilizing NWS products, continuing the trend observed in the previous update. The number of agencies using FAA products bounced back from the 2017 update and now exceeds the level observed during the 2015 update.

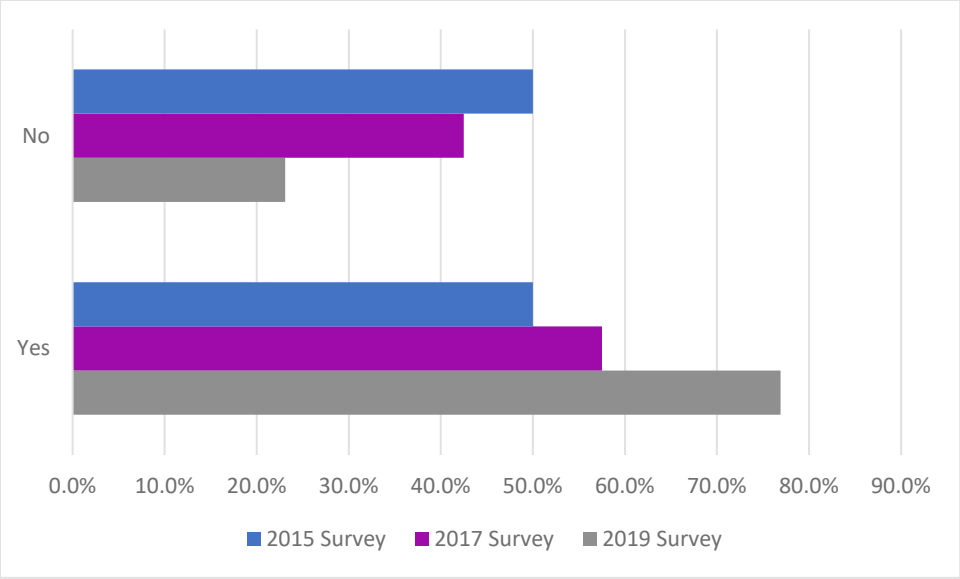


Figure 10. Graph. Percentage of agencies collecting real-time field data from maintenance vehicles

Overall, State DOTs are increasingly collecting real-time field data from maintenance vehicles (see Figure 10). Over three-quarters (76.9%) of respondents to the State DOT survey indicated that their agency collected some form of real-time data from some percentage of their maintenance fleet. Figure 11 shows the distribution for the types of data collected and the percentage of the vehicle fleet by the number of agencies implementing each combination. Plow status and material usage data have the broadest implementation (16 agencies with 50% or more of the fleet equipped), followed closely by atmospheric weather data (15 agencies with 50% or more of the fleet equipped), and road weather conditions data (12 agencies with 50% or more of the fleet equipped).

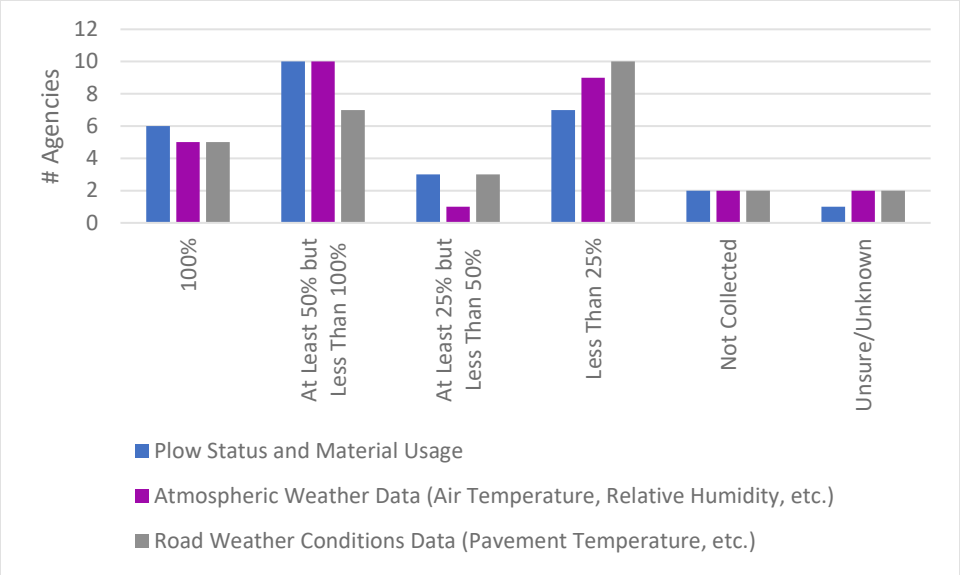


Figure 11. Graph. Number of agencies answering the question, "Which of the following data are collected from the maintenance vehicles, and from what percentage of the applicable fleets?"

Repondents from the State DOT survey reported a total of 2,610 Environmental Sensor Stations (ESS), up from 2,464 in 2017. This is a change from previous updates, where States appeared to be gradually shutting down ESS. A significant majority of respondents (92.1%) indicated ESS data were used to support traffic management and maintenance decision-making. The decreasing trend continued for using ESS data as inputs for segment-level forecasts. Fewer respondents indicated using ESS to provide current conditions to traveler information systems than in previous updates. Figure 12 contains additional information.

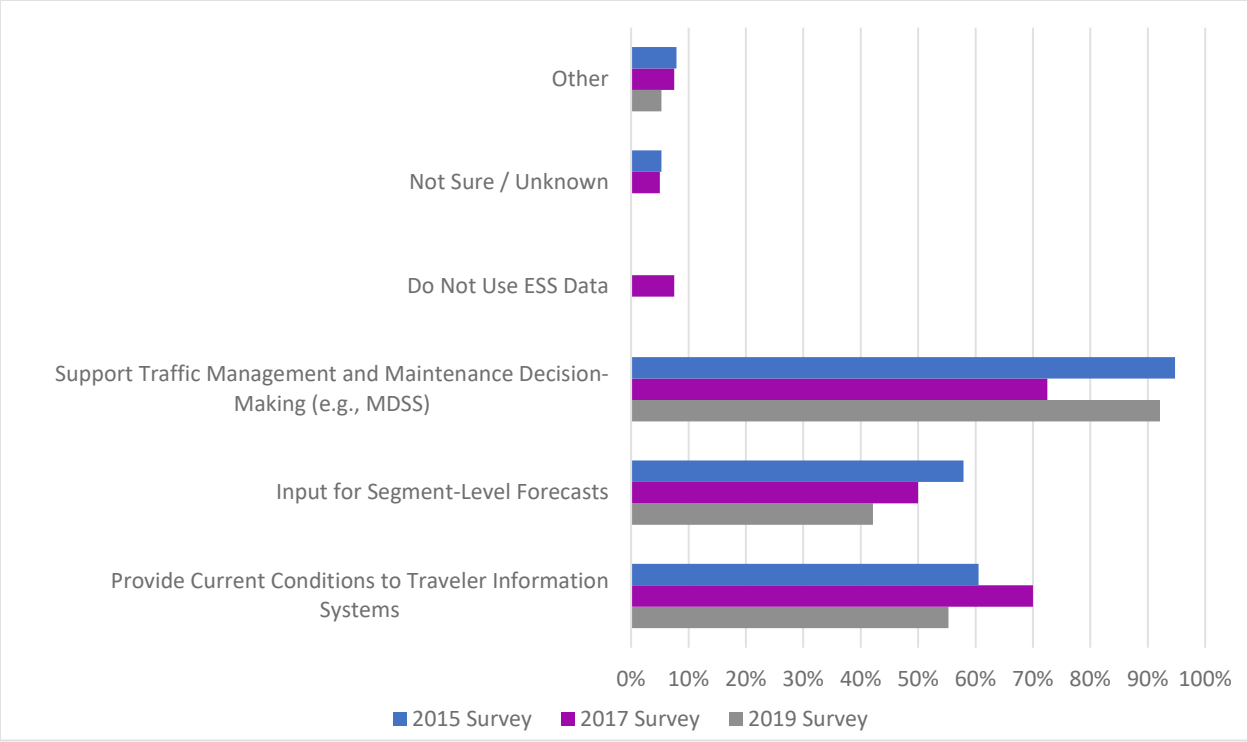


Figure 12. Graph. Use of Environmental Sensor Stations (ESS) at State departments of transportation

Use of Decision Support Tools

The percentage of State DOTs using Maintenance Decision Support Systems (MDSS) has increased from the 2017 update. One-third (33.3%) of State DOT survey respondents indicated statewide use of an MDSS, compared with one-fifth of respondents (20%) in 2017 and one-fourth (25%) in 2015. An additional 12.8% of respondents use an MDSS, but have not deployed such a system statewide. This is a downward trend from the two previous updates, suggesting that agencies are moving from partial deployments to statewide deployments. The number of agencies reporting not having an MDSS has decreased (17.9%, down from 22.5%), along with the number of agencies reporting not needing an MDSS (28.2%, down from 35.0%). This information is presented graphically in Figure 13.

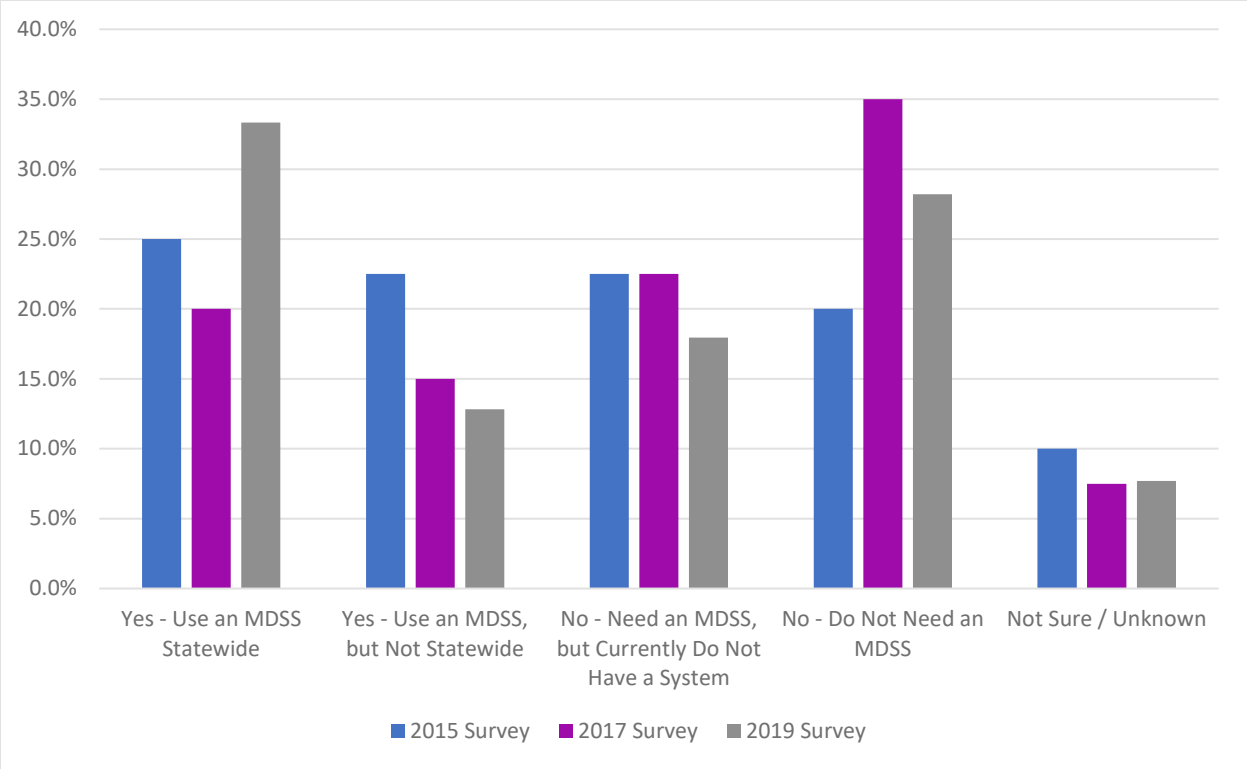


Figure 13. Graph. Percentage of State DOTs indicating use and non-use of Maintenance Decision Support Systems (MDSS)

The percentage of agencies using decision support tools to provide current traveler information has steadily decreased since the 2015 update (see Figure 14). This, combined with the findings of decreasing use of ESS data to provide current conditions on traveler information systems (see Figure 12) suggests that continued promotion of the benefits provided to travelers and the transportation system could be a renewed focus of the RWMP in the period leading to the next update.

All other surveyed uses of decision support tools (coordination with other jurisdictions/agencies, supporting non-winter maintenance activities, traffic control and management, setting seasonal load restrictions) have increased compared to the 2017 update. Notably, this is the second consecutive update where there has been an observed increase in the use of decision support tools to support non-winter maintenance activities such as scheduling or construction coordination.

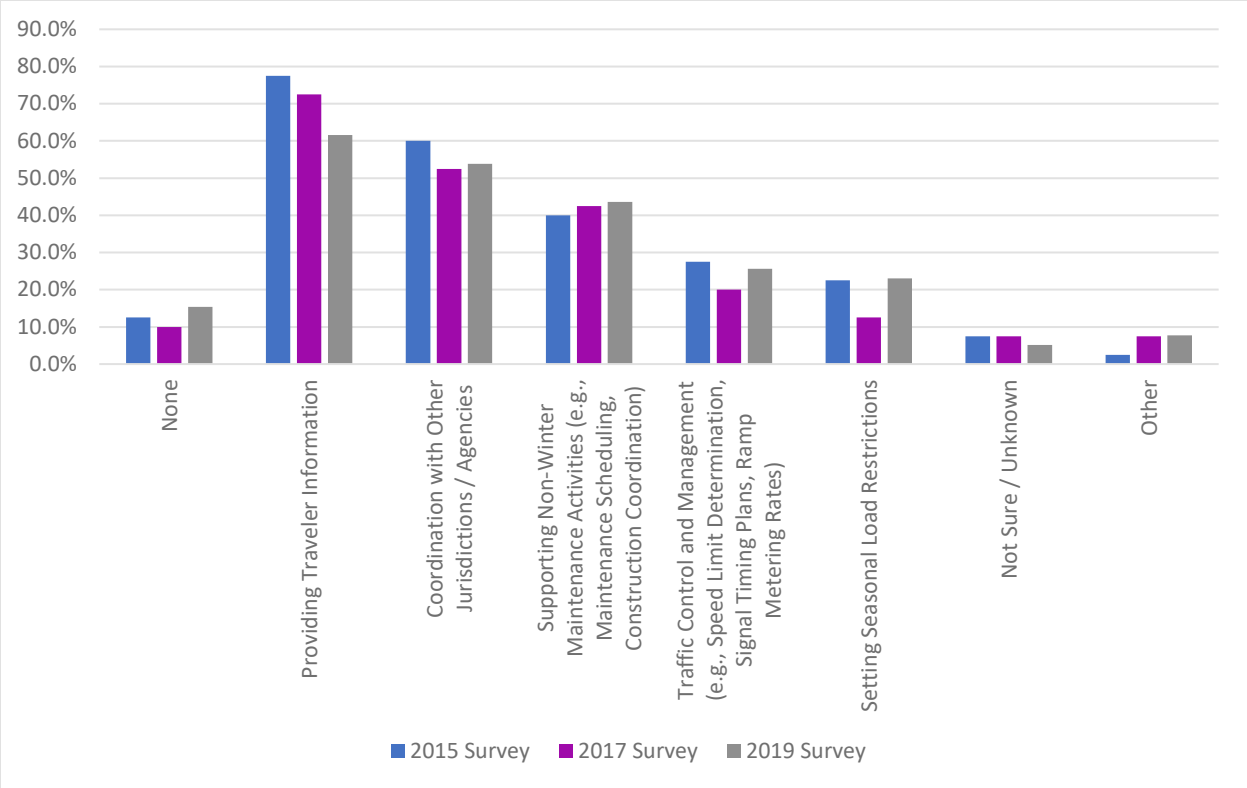


Figure 14. Graph. Percentage of State DOTs using weather related decision support tools for road weather management

A smaller proportion of State DOT respondents either do not use or are not aware of whether their agency used weather-responsive analysis tools and models (83.8% in current update versus 95.0% in previous update). This continues to reflect very low awareness and use of weather-responsive analysis, modeling, and simulation products for road weather. Traffic signal optimization tools are the most frequently used by State DOTs (see Figure 15).

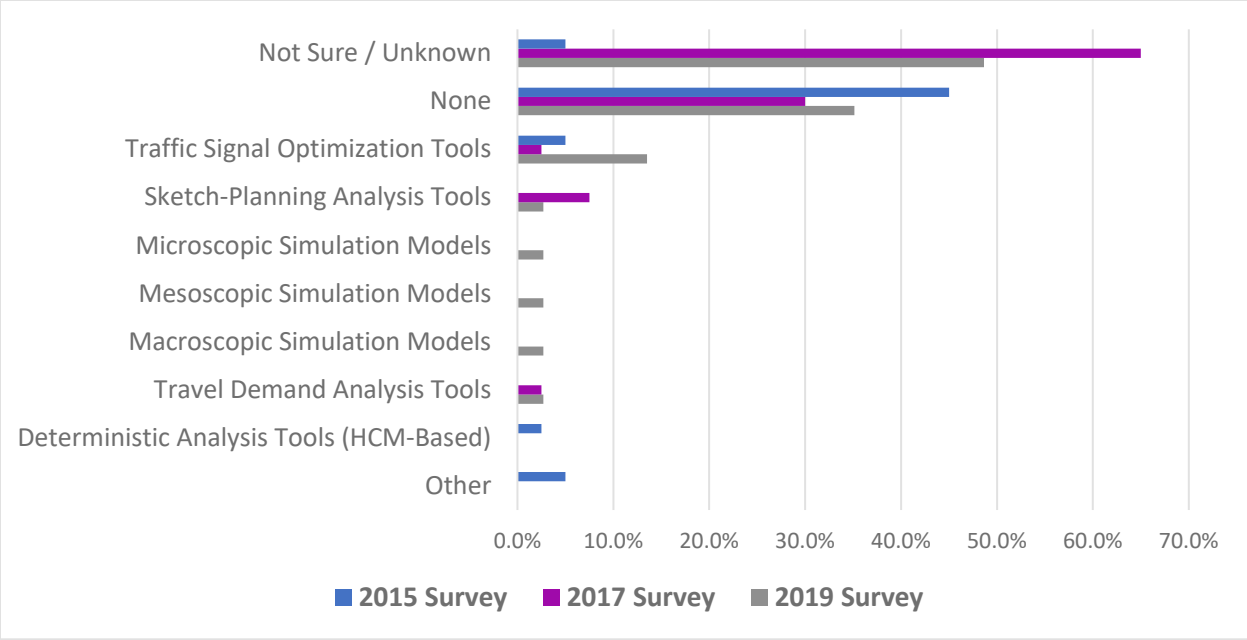


Figure 15. Graph. Percentage of State DOTs using weather-responsive traffic analysis and simulation tools for planning and evaluating road weather management

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

Figure 16 shows the tremendous growth in the number of agencies that have developed or are considering applications that use real-time data from vehicle fleets and vehicle-to-infrastructure (V2I) or infrastructure-to-vehicle technology. In the 2017 update, just 17% of agencies had developed an application and an additional 3% were considering developing an application. In the current update, 44.4% of agencies have developed an application, and an additional 47.2% are considering developing one.

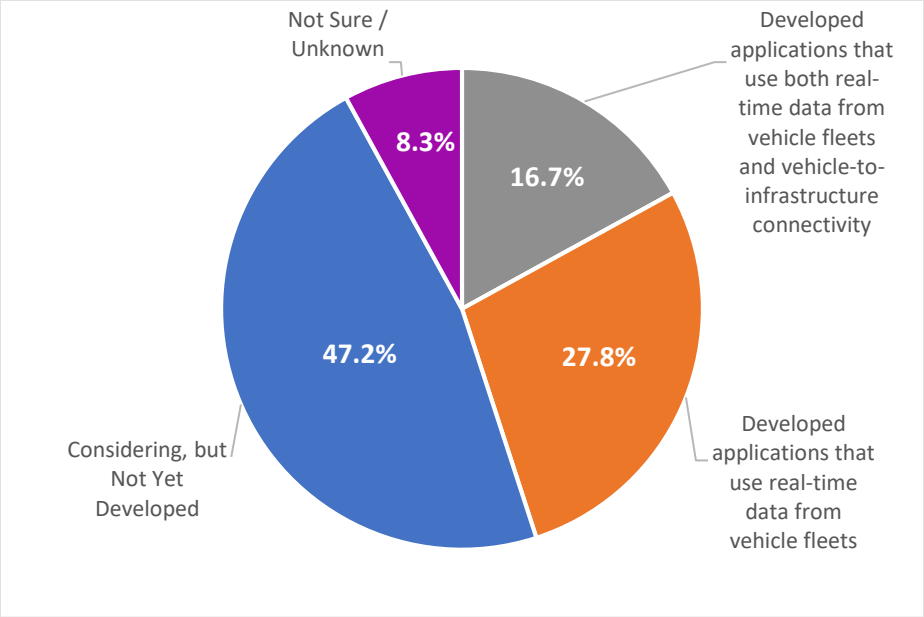


Figure 16. Chart. Survey responses on the use of vehicle-to-infrastructure or infrastructure-to-vehicle connectivity

Consideration of Extreme Weather, Transportation Resilience, and Sustainability

The percentage of agencies that have not participated in the development of any adapation practices has been consistently decreasing since 2015. More agencies are reporting completed vulnerability or risk assessments and implemented resiliency plans for road weather management infrastructure, as seen in Figure 17.

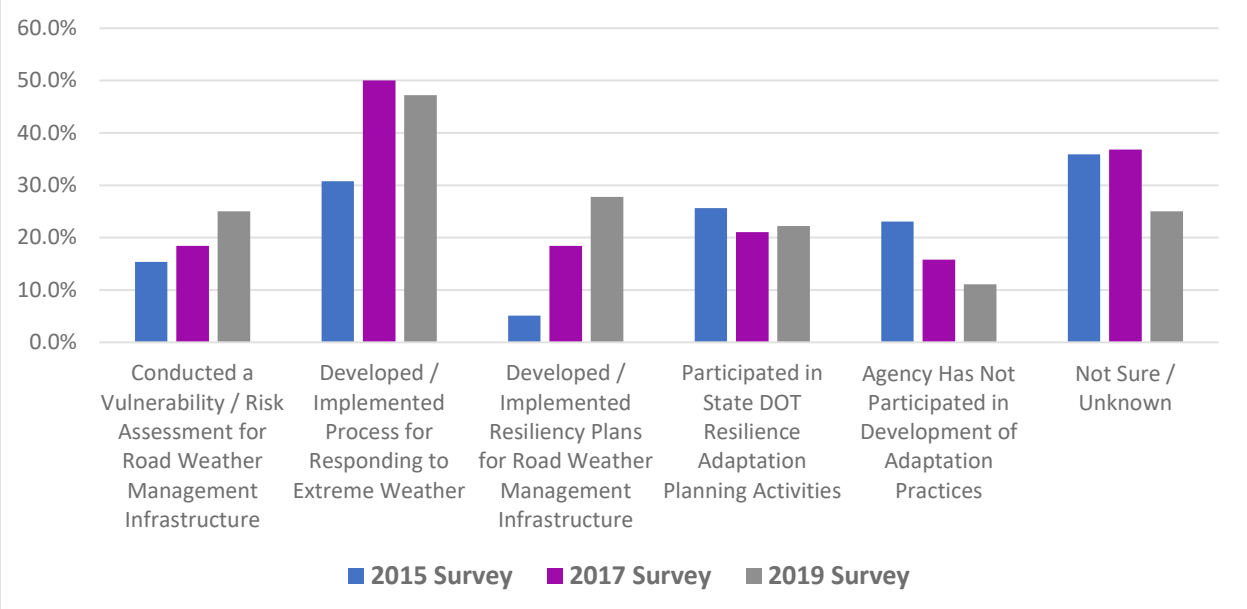


Figure 17. Graph. Percentage of agencies involved in extreme weather or resilience activities

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 Communities of Practice

State DOT participation in meetings and workshops has dramatically increased since the prior update. Notably, an increasing number of States are sending representatives to the annual road weather management stakeholder meeting; 32 State DOTs were represented at the 2019 stakeholder meeting, up from 29 in 2017 and 2018. In addition, there is a growing interest in the Every Day Counts (EDC) innovations for road weather management. In 2018, 5 EDC-5 Summits attracted participants from 48 States. Figure 18 shows the consistent and strong levels of attendance at the various road weather management meetings.

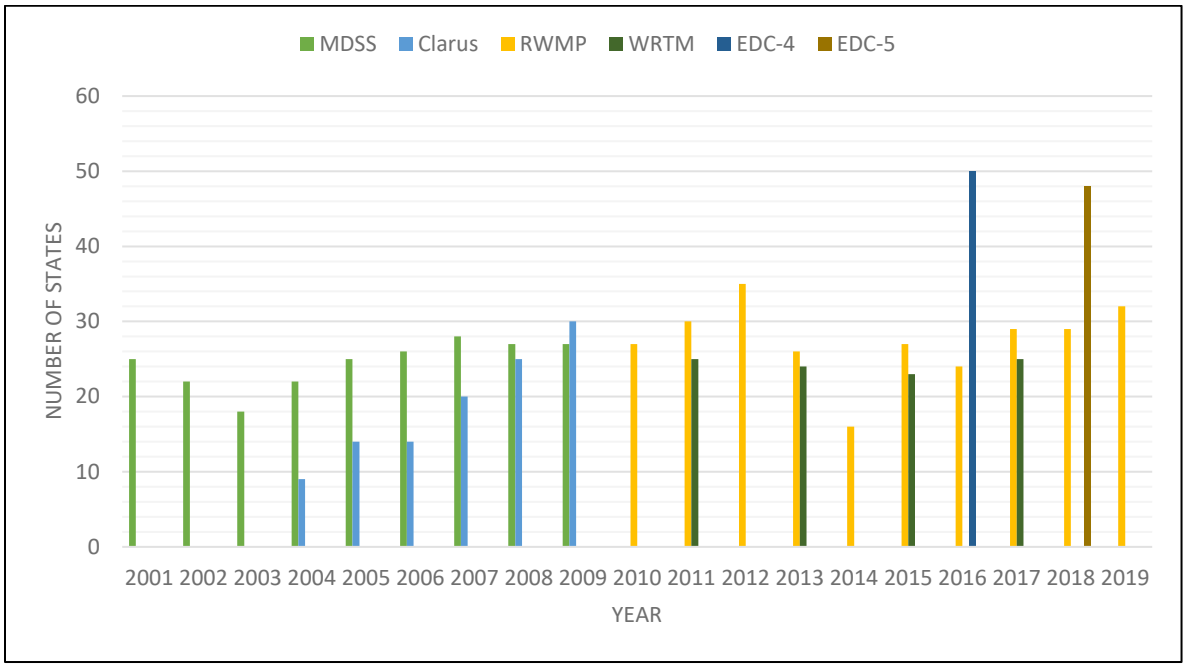


Figure 18. Graph. States participating in road weather management meetings

Participation in Capability Maturity Improvement Workshops

The Federal Highway Administration (FHWA) Office of Operations created six transportation systems management and operations (TSMO) Capability Maturity Frameworks (CMF) to assist agencies in assessing their capabilities within major operations areas and to identify areas for improvement. The Road Weather Management Program (RWMP) facilitates Road Weather Management CMF workshops for all interested agencies, walking participants through the self-evaluation tool, and using the findings to help identify a list of prioritized actions that the agency can use to increase capabilities in road weather management.

Since the 2017 update, an additional 6 agencies have conducted a Road Weather Management CMF workshop, bringing the total number of State DOTs involved up to 16. An additional 4 agencies have expressed interest in hosting a workshop at some time.

Participation in Road Weather Management-Sponsored Training and Webinars

RWMP staff and contractors supported 26 workshops and 13 webinars in 2017, and 28 workshops and 17 webinars in 2018. These events covered a variety of topics of interest to operations and maintenance professionals, including the EDC-4 and EDC-5 initiatives, transportation system resilience as it relates to adverse weather, cost and benefit analyses, and the potential of connected and autonomous vehicles.

Road Weather Management Engagement with Stakeholders in Public Conferences

The content, topics, sponsors, and attendees evolve among the road weather management workshops or conferences, and the reliability of attendance data can vary. It therefore is difficult to draw conclusions by comparing one event to another. Rather, the RWMP compiles reported attendance (number of participants and number of State agencies) to derive a broad idea of the national interest and involvement in road weather management topics. All public activities and the associated number of participants and agencies represented are shown in Table 3. RWMP staff and contractors regularly make presentations, briefings, and demonstrations at various workshops and conferences, which extends the reach of the program beyond its own activities. Some of these activities also are listed in Table 3. For the 2017-2019 reporting period, RWMP staff and contractors attended or facilitated at least 137 conferences, meetings, or peer exchanges, reaching well over 9,400 participants.

Table 3. Meetings with Road Weather Program Representation, 2017-2019

Year	Road Weather Program Activities, 2017-2019	Number of Participants	Number of State Agencies
2017	Chicago Analysis, Modeling, & Simulation (AMS) Stakeholder Meeting, Chicago, IL	17	5
2017	American Meteorology Society 2017 Annual Meeting, Seattle, WA	80	N/A
2017	Aurora Pooled Fund Meeting, Salt Lake City, UT	27	19

Year	Road Weather Program Activities, 2017-2019	Number of Participants	Number of State Agencies
2017	IMRCP Stakeholder Webinar	35	10
2017	Clear Roads Pooled Fund Meeting	20	15
2017	Resilience to Extreme Weather Events Workshop	25	10
2017	AMS Washington Forum	150	2
2017	Road Weather Management Stakeholder Meeting	140	29
2017	4th National Weather Responsive Traffic Management Stakeholder Meeting	70	25
2017	AASHTO Subcommittee of Transportation System Management & Operations Annual Meeting: Weather Workshop, SD	55	25
2017	Weather-Savvy Roads Webinar for Local Communities	100	N/A
2017	Road Weather Management Regional Roundtable #1	33	10
2017	Road Weather Management Regional Roundtable #2	30	12
2017	Road Weather Management Regional Roundtable #3	31	14
2017	Pikalert Peer Exchange	25	6
2017	AASHTO Summit on Resiliency for Extreme Weather and Climate Change, DC	150	20
2017	Optimal Messaging for Dynamic Message Signs	50	25
2018	American Meteorology Society 2018 Annual Meeting, Austin, TX	130	N/A
2018	TRB Annual Meeting, Washington, DC	25	8
2018	Office of Policy about Transportation Data & Governance—Policy Symposium	20	8
2018	CMF and Resilience Overlay Webinar	N/A	N/A
2018	Road Weather Management Regional Roundtable #1	31	11
2018	Road Weather Management Regional Roundtable #2	32	15
2018	Road Weather Management Regional Roundtable #3	31	11
2018	Every Day Counts (EDC-4)/Effective Weather Messaging	N/A	N/A
2018	Weather Responsive Traffic Management Using Connected Vehicle Data	N/A	N/A
2018	Aurora Spring Meeting, Seattle, WA	35	20

Year	Road Weather Program Activities, 2017-2019	Number of Participants	Number of State Agencies
2018	ITS Virginia Annual Meeting	80	1
2018	National Webinar: Deployment of CV-Enabled WRTM	125	22
2018	APWA North American Snow Conference	50	1
2018	EDC-4/Weather-Savvy Roads Webinar	100	3
2018	NWS Winter Weather Program Meeting	30	N/A
2018	AASHTO Connected and Automated Technology Coalition: IOO/OEM Forum	40	15
2018	Salt Management Strategies TOPS-Advisory Committee	47	2
2018	National Webinar: Enhancing Transportation Systems Operations Capabilities to Address Weather and Climate Trends	30	10
2018	National Dialogue Launch, MI	150	25
2018	Automated Vehicle Symposium, CA	32	4
2018	2018 AASHTO Maintenance Committee Meeting, NC	400	45
2018	2018 AASHTO Winter Technical Service Program Meeting, NC	N/A	N/A
2018	EDC-5 Kickoff Meeting	N/A	N/A
2018	CMF Workshop: Weather Resilience & CMF	30	3
2018	National Weather Association Annual Meeting, MO	300	N/A
2018	AASHTO Committee on Transportation Systems Operations	120	25
2018	National Webinar: IMRCP	64	14
2018	National Dialogue, Seattle, WA	N/A	N/A
2018	National Dialogue, Atlanta, GA	N/A	N/A
2018	2018 Road Weather Management Stakeholder Meeting	142	29
2018	EDC-5 Pre-Deployment Webinar 1	50	10
2018	EDC-5 Pre-Deployment Webinar 2	50	10
2018	American Meteorology Society: Automated Vehicles & Meteorology Summit	90	N/A
2018	TRB: Resilience Innovations Summit & Exchange	40	10
2018	National Dialogue, Phoenix, AZ	130	20

Year	Road Weather Program Activities, 2017-2019	Number of Participants	Number of State Agencies
2018	American Public Works Association (APWA): Click, Listen & Learn Webinar	25	2
2018	EDC-5, Baltimore, MD	250	8
2018	EDC-5, Albany, NY	N/A	N/A
2018	EDC-5, St. Louis, MO	30	8
2018	National Dialogue, Dallas, TX	200	25
2018	EDC-5, Portland, OR	300	12
2018	EDC-5, Orlando, FL	N/A	N/A
2018	Road Weather Management Regional Roundtable #1	34	13
2018	Road Weather Management Regional Roundtable #2	32	11
2018	Road Weather Management Regional Roundtable #3	31	12
2019	American Meteorology Society 2019 Annual Meeting, Phoenix, AZ	90	N/A
2019	TRB Annual Meeting, Washington, DC	25	7
2019	Northwest Passage Pooled Fund Study	N/A	N/A
2019	AASHTO Committee on Transportation Systems Operations (CSO)	65	30
2019	IMRCP Stakeholder Group	17	5
2019	Aurora Pooled Fund Meeting, San Diego, CA	30	20

Chapter 5. Partnerships and Stakeholder Collaboration

OVERVIEW

Through partnerships and stakeholder collaboration, the Road Weather Management Program (RWMP) utilizes a multidisciplinary 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 that the RWMP is fostering and encouraging effective partnerhsips and stakeholder collaboration.

PERFORMANCE FINDINGS

Participation in Road Weather Program Research and Development Activities

Information sharing and collaboration are fundamental to road weather management. The RWMP facilitates these by partnering with State and local transportation agencies to advance various research and development (R&D) projects. Figure 19 shows three of these projects: the Pathfinder Initiative, Integrated Mobile Observations (IMO) program, and Road Weather Management Capability Maturity Framework (RWM CMF). All three projects have shown continued growth since the 2015 update, indicating the success of the RWMP's outreach and collaboration efforts.

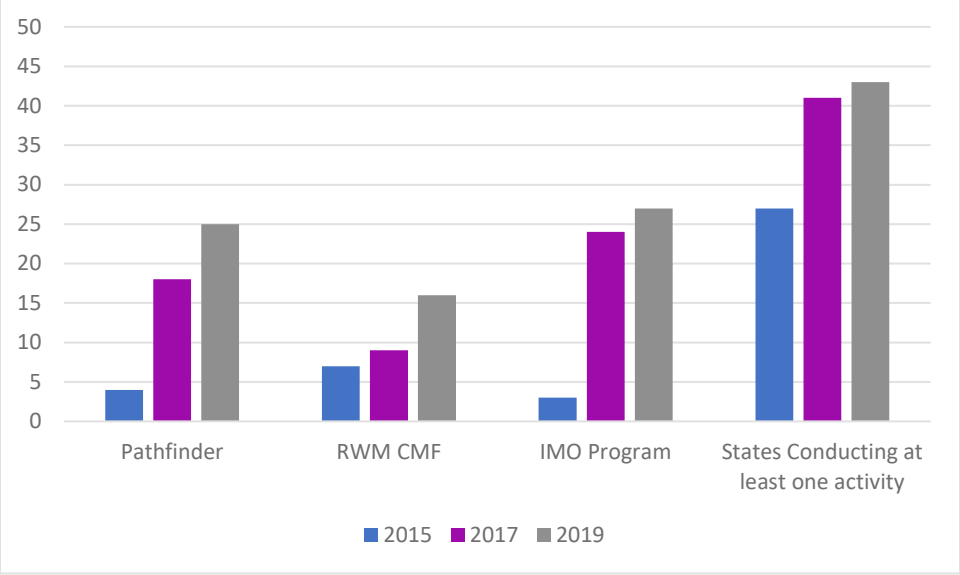


Figure 19. Graph. Number of agencies participating in road weather research and development projects

Participation in Meteorological Assimilation Data Ingest System

The RWMP supports the 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. Since 2017, the number of respondents to the State DOT survey indicating their agency subscribed to NOAA's Meteorological Assimilation Data Ingest System (MADIS) dropped from 21 to 13. One reason could be that the MADIS system has still not deployed the QA/QC algorithms that were specifically identified by the DOTs. As NOAA development of MADIS continues, the usage by State DOTs may increase once the QA/QC requirements of the DOTs are available in production.

Engagement with the National Weather Service

Local weather forecast information is a critical input in road weather management and operations decision-making. The RWMP also supports the National Weather Service (NWS) by encouraging State DOTs to use tools such as NWSchat, which gives DOTs access to real-time weather forecasts. The RWMP tracks the number of agencies that coordinate with their local forecast offices for assistance in road weather management and operations (see Figure 20). Every respondent (100%) indicated that their agency worked with their local forecast offices, with over 70% indicating routine coordination during inclement weather events. As part of Pathfinder, engagement with the NWS also includes greater coordination with the private sector weather providers.

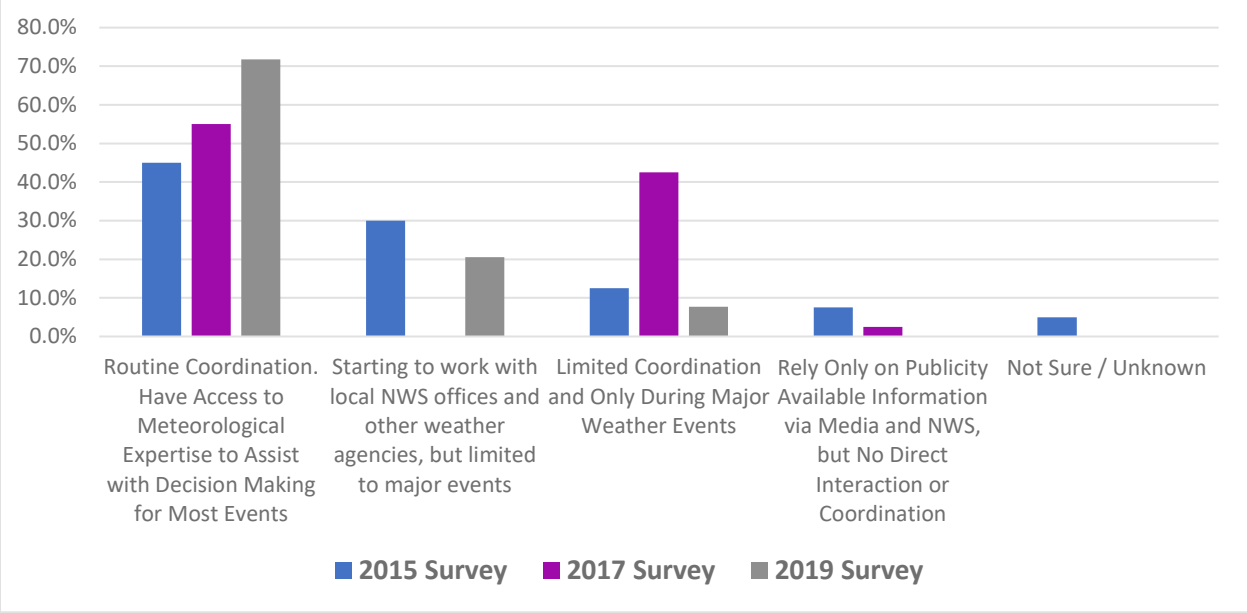


Figure 20. Graph. Level of coordination between State DOTs and NWS local forecast offices

Chapter 6. Recommendations and Conclusions

The Road Weather Management Program (RWMP) is at a crucial point in its program evolution, with close to 15 years of research and development, stakeholder engagement, and accomplishments. Overall, the program's role in enabling improved management of the transportation system during adverse weather is evident in the strong growth in use of tools, programs, and activities by the State departments of transportation (DOTs). In the last few years, particularly in the time period of this update, the program has focused on advancing the deployment of proven strategies through the EDC initiative. The selected EDC-4 (Weather-Savvy Roads) and EDC-5 (Weather Responsive Management Systems) initiatives have allowed the program to largely focus efforts on advancing deployment of four major strategies—Integrated Mobile Observations, Pathfinder, Weather Responsive Traffic Management, and Weather Responsive Maintenance Management Systems. As a consequence, the performance measurement show sustained interest and growth in all four of these strategies around the United States. As the EDC-4 and EDC-5 intiatives ramp down, the question becomes: What are the next steps for the program in terms of supporting the advancement of road weather management practices? The 2019 performance measurement provides some clues about likely needs and requirements for the program, including:

- **Need for more case studies on material management practices, especially documenting approaches that State DOTs have taken** to optimize their usage of salt. Aside from ancedotal information, it is hard to find recent published results on this topic. Similarly, statistics about road weather impact are getting dated and need to be refreshed. New private sector data, including the National Performance Measurement Research Data Set, may provide approaches to rapidly assess road weather impacts on delays and congestion. Similarly, more information about route optimization, reduction of deadhead time and miles are expected to be major initiatives at the State DOTs in upcoming years.
- **Need to re-engage State DOTs around Road Weather Information System (RWIS) data sharing.** This update revealed that State DOT contributions to MADIS have regressed. While 5 new States have a signed MADIS data sharing agreement, 13 have dropped from the program, according to the State DOT survey. The role of RWIS data sharing may re-emerge as a priority especially with other voluntary data exchanges being developed to support automated driving systems (ADS). RWMP's *Clarus* initiative and transition to MADIS in some ways was ahead of its time in terms of creating a voluntary data exchange of road weather sensor data, but quality-checked road weather sensor data continues to be a priority for ADS development. However, it is important to note that the development of the MADIS system is outside the control of the RWMP and subject to NOAA's research priorities and resource availabilty. It is likely that once MADIS deploys the QA/QC algorithms used in *Clarus* to production, the utility of the system to DOTs will increase.
- **Overall, there is significant growth in the use of data generated from vehicle platforms for road weather maintenance**. More than three quarters of State DOTs

collect mobile observations from their vehicle fleets. Of the 39 State DOTs surveyed, 30 (76.9%) reported collecting real-time field data from maintenance vehicles. This is up from 23 State DOTs from the prior period (57.5%). Compared to the 2017 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). Maintaining these advancements requires the RWMP to **support overall maturity in the use of these systems, including data management practices, application development, and operations and maintenance of these systems.**

- **A map of survey respondents and analysis of State involvement reveal a clear geographical gap in engagement with the southeastern States.** This may result in part from the program's historic focus on winter weather-related activities. However, the non-winter related roadway management needs are growing with hurricanes, flooding, dust storms creating sustained pressures on the State DOTs to respond. The RWMP can better understand the needs of States that are routinely affected by non-winter events by broadening outreach efforts to include assessing road weather impacts from flooding, hurricanes, dust storms, etc.

Overall, 2017-2019 have seen continued advancements in use of road weather management tools and practices supported by the RWMP. Interest among stakeholders is strong and has continued to grow since the last update. More States are being engaged by the program through workshops, training, technical assistance, and research and development.

Appendix A: State Department of Transportation Survey

This appendix summarizes the State departments of transportation (DOT) survey questions and results.

Q4. Does your agency regularly collect and report road weather performance measures? (This may include dashboards, winter maintenance reports, seasonal summaries, etc.)

Related performance measure (PM): Number of agencies that collect and report road weather-related performance measures to the public.

Table 4. State DOT Survey Question 4 and Associated Reponses

Answer Options	Percentage
Yes	62%
No	31%
Unsure/Not known	8%
Number Responded	39
Number Skipped	0

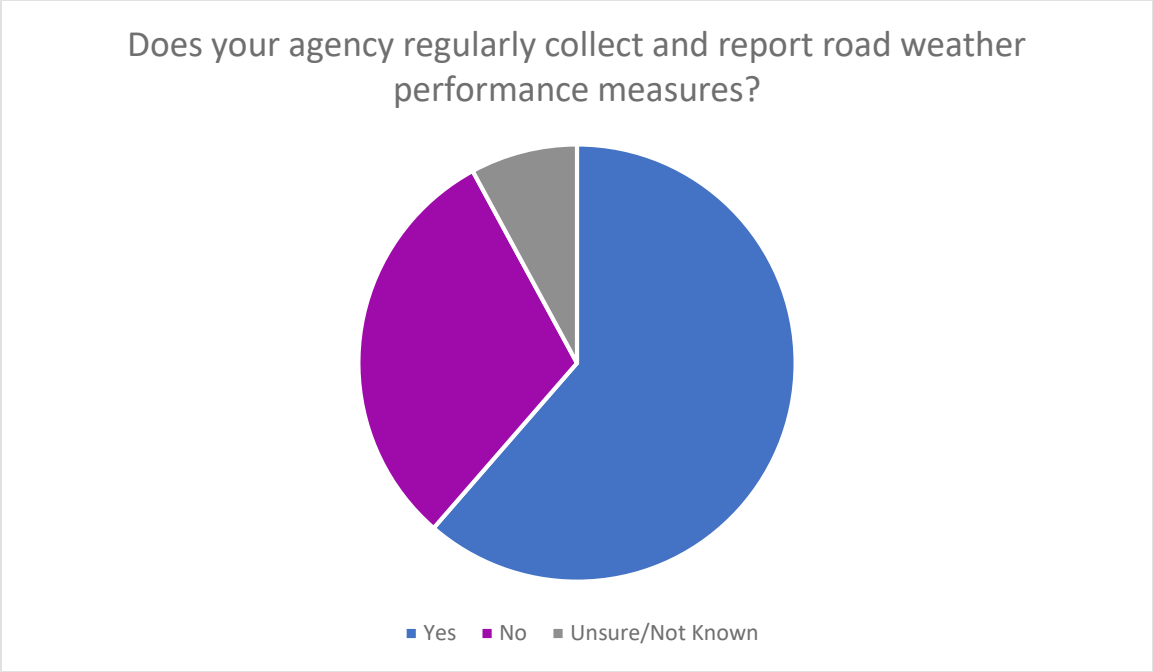


Figure 21. Chart. Responses from State department of transportation survey question 4

Q5. Does your agency calculate a "winter severity index" to compare performance across events or across years?

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

Table 5. State DOT Survey Question 5 and Associated Reponses

Answer Options	Percentage
Yes	46%
No	41%
Unsure/Not known	13%
Number Responded	39
Number Skipped	0

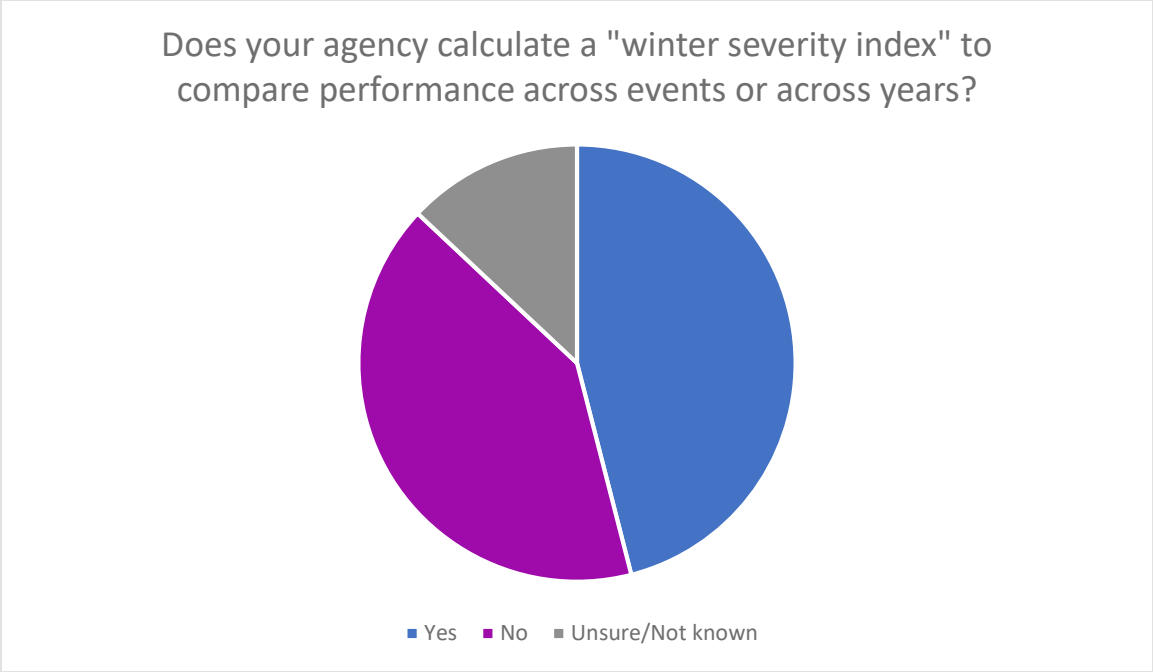


Figure 22. Chart. Responses from State department of transportation survey question 5

Q6. Does your agency have a process for evaluating the return on investment (ROI) or net benefits of road weather management investments?

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

Table 6. State DOT Survey Question 6 and Associated Reponses

Answer Options	Percentage
Yes	10%
No	72%
Unsure/Not known	18%
Number Responded	39
Number Skipped	0

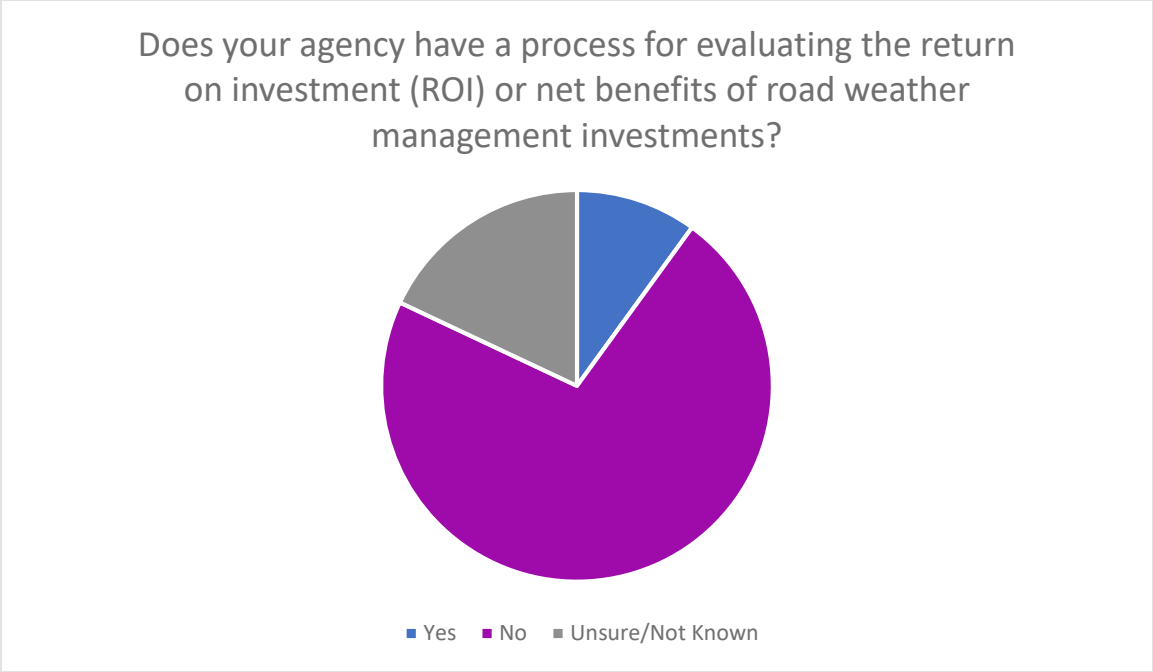


Figure 23. Chart. Responses from State department of transportation survey question 6

Q7. What are

your agency's sources of weather and road weather information? (Check all that apply):

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

Table 7. State DOT Survey Question 7 and Associated Responses[10]

Answer Options	Response Count	Percentage
Fixed Agency Sensors (RWIS)	37	94.9%
Mobile Agency Sensors (IMO)	22	56.4%
Private Weather Service Providers	26	66.7%
Agency Field Personnel	31	79.5%
Public/Social Media	30	76.9%
FAA Products (ASOS, AWOS)	16	41.0%
National Weather Service Products	33	84.6%
NOAA's MADIS	7	17.9%
USGS Earthquake Alerts	8	20.5%

[10] 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 = U.S. Geological Survey

Answer Options	Response Count	Percentage
Not Sure/Unknown	0	0.0%
Other	5	12.8%
# Respondents Who Answered Question	39	
# Respondents Who Skipped Question	0	

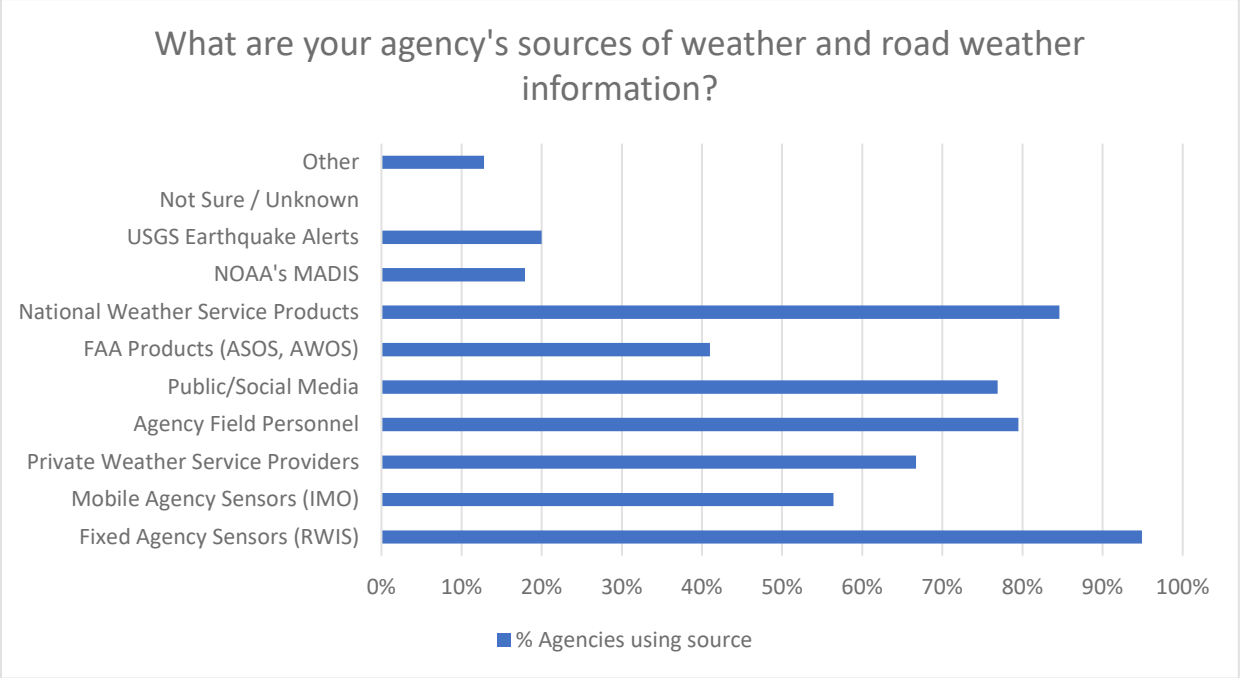


Figure 24. Graph. Responses from State department of transportation survey question 7

Other responses included:

- Iowa Environmental Mesonet
- Fleet deployment
- Phone a friend
- In-house meteorologist
- MDSS

Q7.1: Does your agency have a signed data sharing agreement with the following? (Check all that apply):

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

Table 8. State DOT Survey Question 7.1 and Associated Responses

Answer Options	Number of Responses	Percent of Responses
Weather Data Environment (WxDE) Data Sharing Agreement with FHWA	11	29%
MADIS Data Sharing Agreement with NOAA	12	32%
Private/Third Party	18	47%
Not Sure/Unknown	11	29%
Other (Please Specify):	6	16%
# Respondents Who Answered Question	38	
# Respondents Who Skipped Question	1	

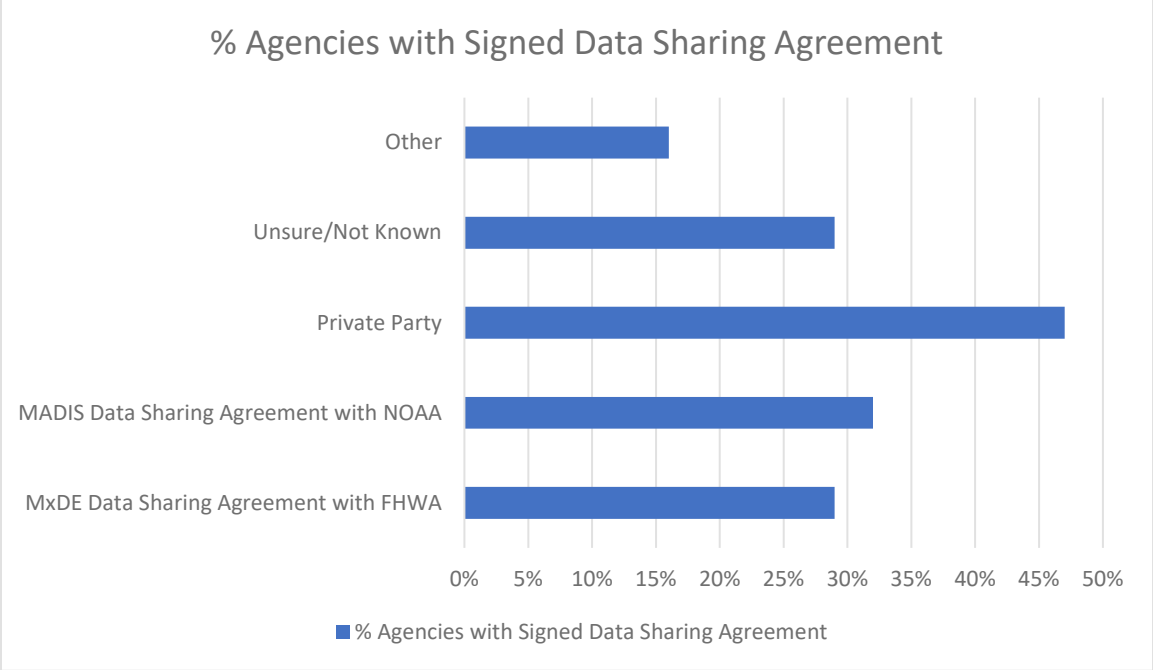


Figure 25. Graph. Responses from State department of transportation survey question 8

Other responses included:

- FAA
- Vaisala Corp

- We have something that was signed to allow Vaisala to share our RWIS data with MADIS. We also have an agreement with Waze, but not sure if it gets into anything relating to weather.
- I believe we're sharing data with FHWA, but am uncertain.
- We share our weather data but a signed agreement is not required.
- Our data is freely available. Agreement was questioned by the AG office.

Q8. Does your agency collect real-time field data from maintenance vehicles?

Related PM: Number of State DOTs collecting mobile observations of road weather data from vehicle fleets.

Table 9. State DOT Survey Question 8 and Associated Responses

Answer Options	#	%
Yes	30	76.9%
No	9	23.1%
Not Sure/Unknown	0	0.0%
# Respondents Who Answered Question	39	
# Respondents Who Skipped Question	0	

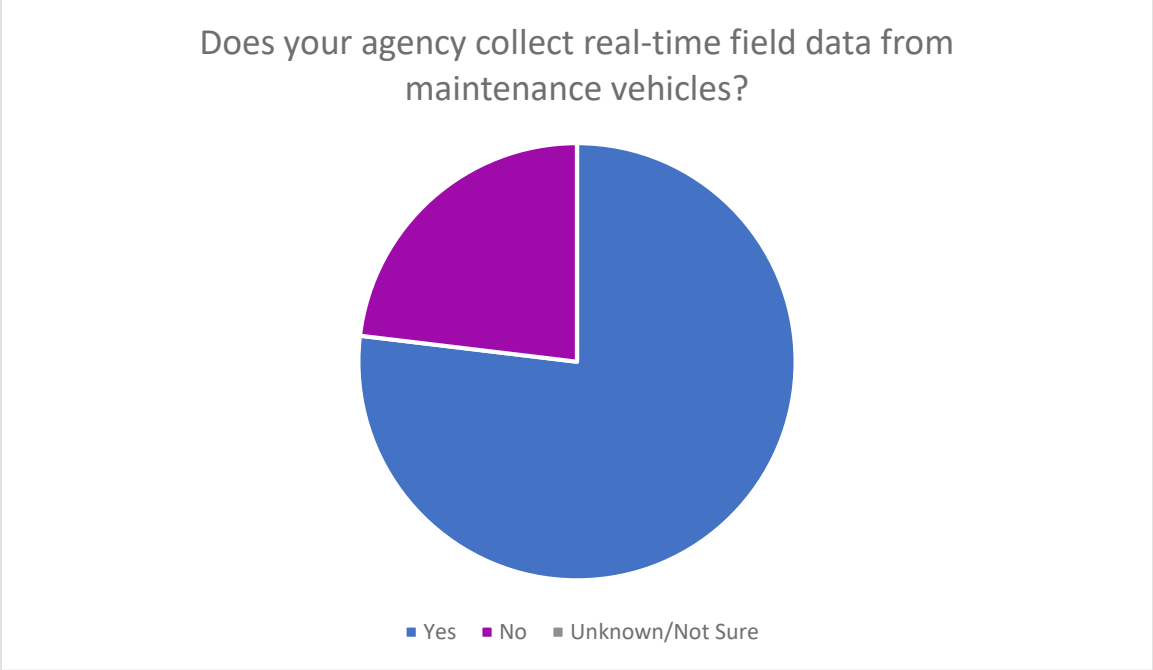


Figure 26. Chart. Responses from State department of transportation survey question 8

Q8.1. If you answered "Yes" to question #8, which of the following data are collected from maintenance vehicles, and from what percentage of the applicable fleets? (Check all that apply):

Related PM: Number of State DOTs collecting mobile observations of road weather data from vehicle fleets.

Table 10. State DOT Survey Question 8.1 and Associated Responses

	100%	At Least 50% but Less Than 100%	At Least 25% but Less Than 50%	Less Than 25%	Not Collected	Unsure / Unknown	Total	% Collecting Mobile Observations
Plow Status and Material Usage	6	10	3	7	2	1	29	89.7%
Atmospheric Weather Data (Air Temperature, Relative Humidity, etc.)	5	10	1	9	2	2	29	86.2%
Road Weather Conditions Data (Pavement Temperature, etc.)	5	7	3	10	2	2	29	86.2%

Q9. How many Environmental Sensor Stations (ESS) does your state agency operate statewide?

Related PM: Number of State DOTs reporting the use of Environmental Sensor Stations (ESS) in operations and maintenance activities.

Table 11. State DOT Survey Question 9 and Associated Responses

Total ESS Sites	2,610
# States Responded	35
# States Skipped	3

Q9.1. Describe how you use your ESS (Check all that apply):

Related PM: Number of State DOTs reporting the use of Environmental Sensor Stations (ESS) in operations and maintenance activities.

Table 12. State DOT Survey Question 9.1 and Associated Responses

Answer Options	#	%
Provide Current Conditions to Traveler Information Systems	21	55.3%
Input for Segment-Level Forecasts	16	42.1%
Support Traffic Management and Maintenance Decision-Making (e.g., MDSS)	35	92.1%
Not Sure/Unknown	0	0.0%
Other	2	5.3%

# Respondents Who Answered Question	38
# Respondents Who Skipped Question	1

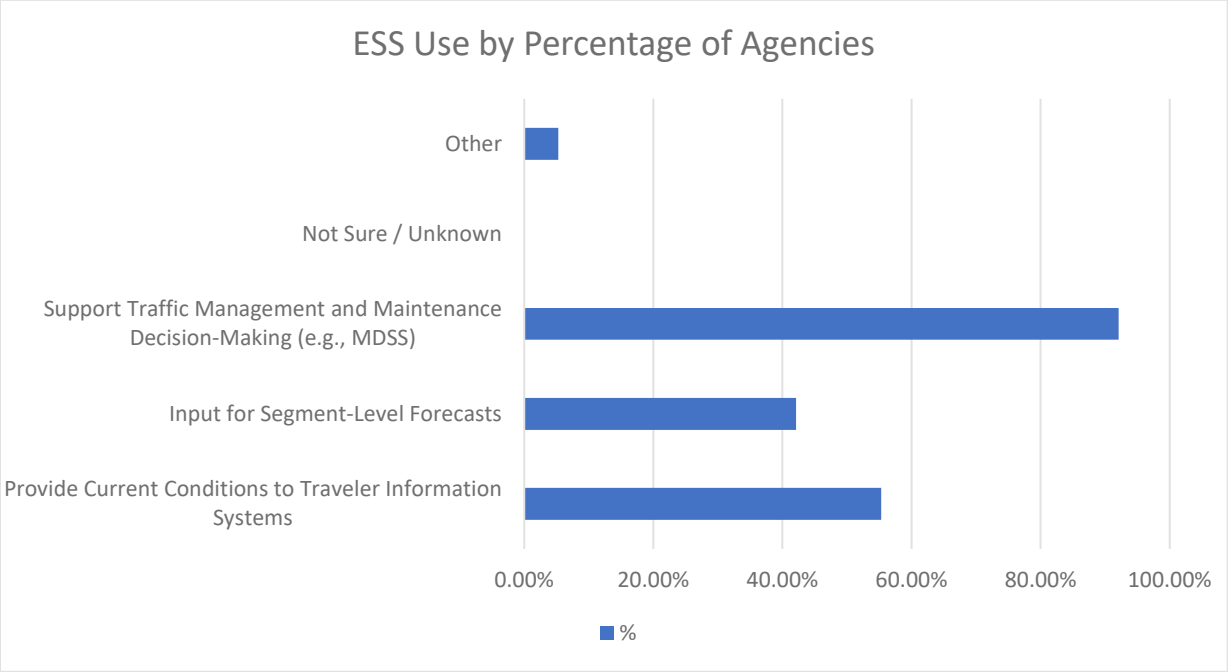


Figure 27. Graph. Responses from State department of transportation survey question 9.1

Q10. Has your agency developed applications or tools that rely on availability of real-time mobile data from vehicle fleets and/or vehicle-to-infrastructure connectivity?

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

Table 13. State DOT Survey Question 5 and Associated Reponses

Answer Options	Percentage
Developed applications that use both real-time data from vehicle fleets and vehicle-to-infrastructure connectivity	17%
Developed applications that use real-time data from vehicle fleets	28%
Considering, but Not Yet Developed	47%
Not Sure/Unknown	8%
Number Responded	36
Number Skipped	3

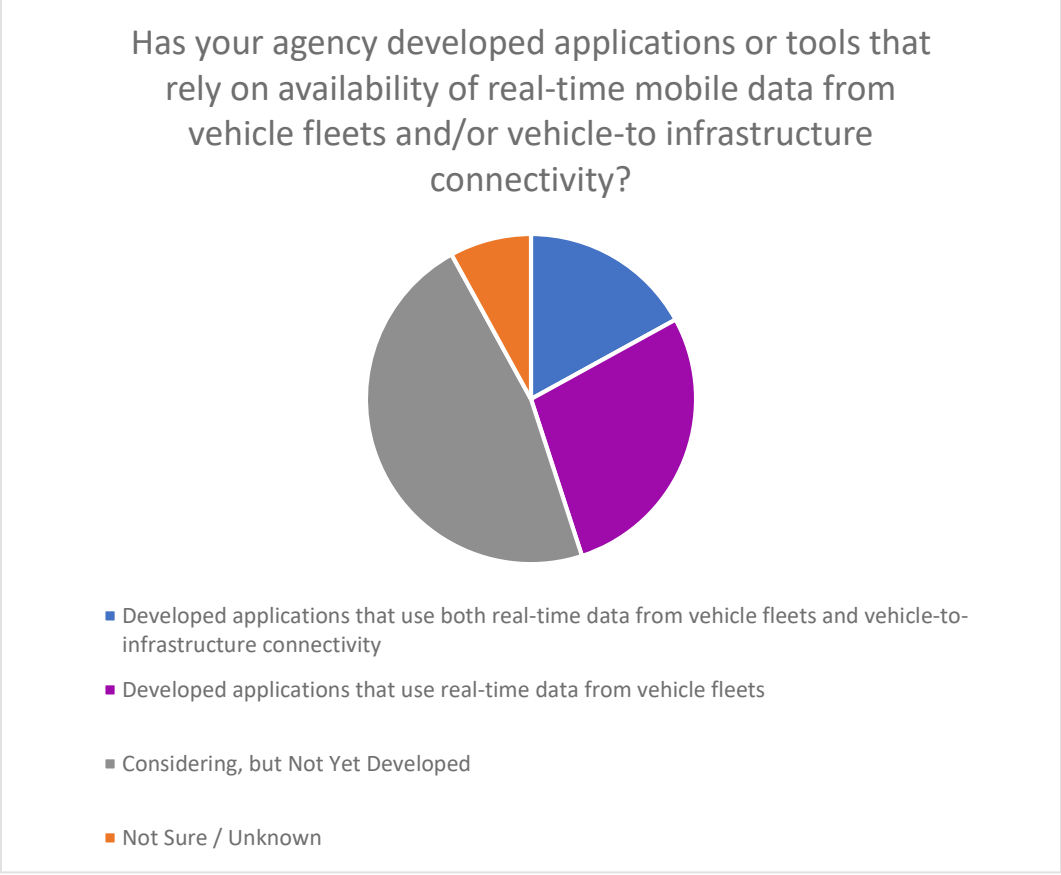


Figure 28. Chart. Responses from State department of transportation survey question 10.

Q11. Describe the level of deployment in your agency of the following road weather information strategies. (Check all that apply):

Related PM: Number of states disseminating advisory weather and road weather information to travelers.

Table 14. State DOT Survey Question 10 and Associated Reponses

	Deployed Statewide (or in all applicable locations)	Limited or Partial Deployment	Not Yet Deployed	Unsure / Unknown	Skipped
Atmospheric Weather Information on Dynamic Message Signs	28.2%	43.6%	25.6%	0.0%	2.6%
Road Condition Information on Dynamic Message Signs	59.0%	38.5%	0.0%	2.6%	0.0%
Road Condition Information on Highway Advisory Radio	48.7%	41.0%	10.3%	0.0%	0.0%
Road Condition Information on Agency-Hosted Social Media (Twitter, Facebook, etc.) or Mobile Applications	23.1%	33.3%	28.2%	10.3%	2.6%
Road Condition Information on Agency-Hosted Websites or 511 Phone Systems	76.9%	15.4%	2.6%	5.1%	0.0%
# Respondents Who Answered Question	39				
# Respondents Who Skipped Question	0				

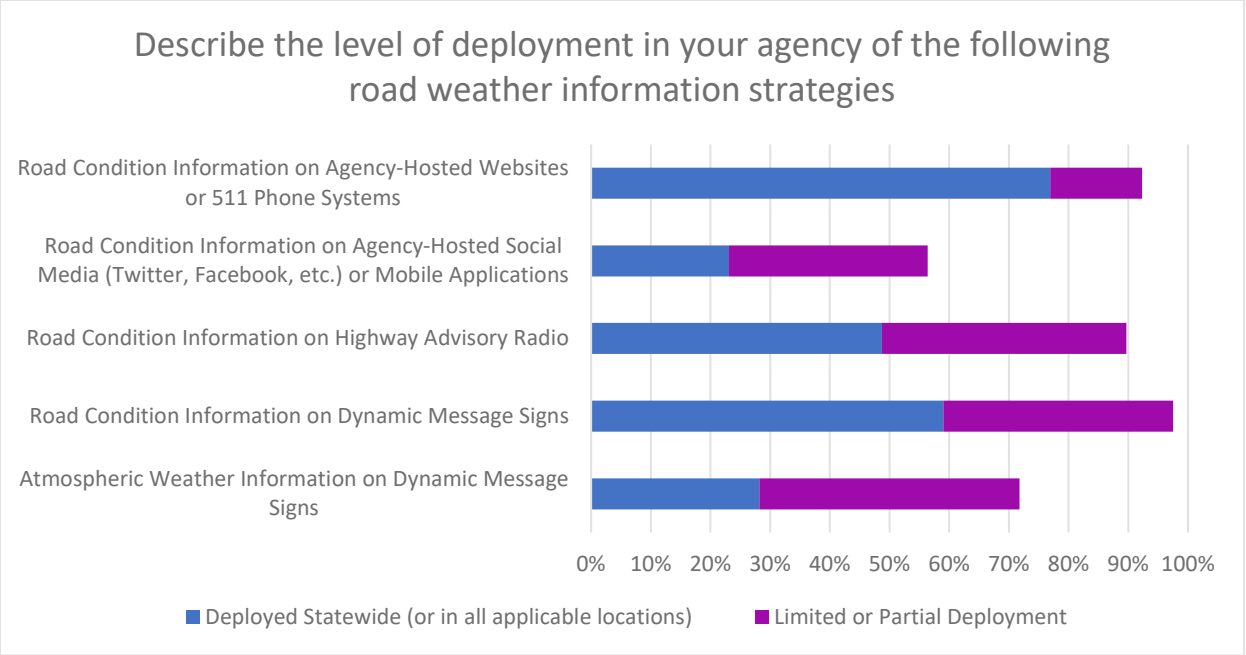


Figure 29. Graph. Responses from State department of transportation survey question 11.

Q11.1. Was your agency's decision to deploy any of the road weather information strategies identified influenced by FHWA's Pathfinder initiative?

Related PM: Number of states disseminating advisory weather and road weather information to travelers.

Table 15. State DOT Survey Question 11.1 and Associated Responses

Answer Options	#	%
Yes	21	57%
No	10	27%
Not Sure/Unknown	6	16%
# Respondents Who Answered Question	37	
# Respondents Who Skipped Question	2	

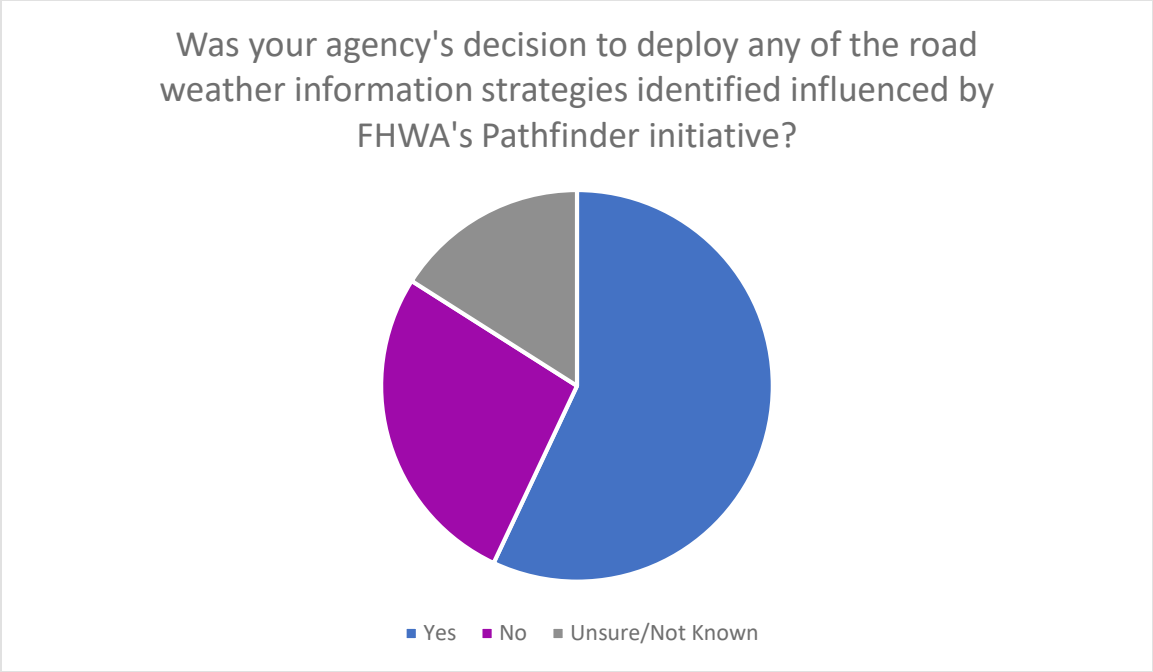


Figure 30. Chart. Responses from State department of transportation survey question 11.1.

Q12. Has your agency deployed safety warning systems related to road weather events?

Related PM: Number of states disseminating advisory weather and road weather information to travelers

Table 16. State DOT Survey Question 12 and Associated Responses

Answer Options	#	%
Yes	19	50%
No	15	39%
Not Sure/Unknown	4	11%
# Respondents Who Answered Question	38	
# Respondents Who Skipped Question	1	

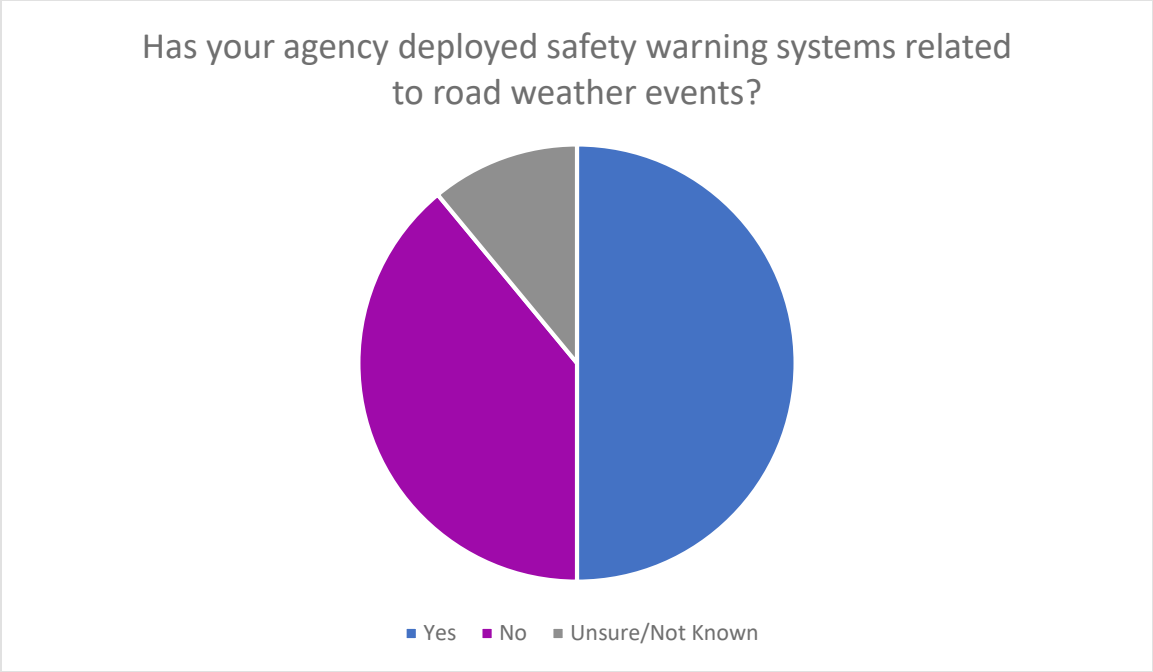


Figure 31. Chart. Responses from State department of transportation survey question 12

Q12.1. If you answered "Yes" to question #12, please select which types of hazards are included in your agency's safety warning system(s). (Check all that apply):

Related PM: Number of states disseminating advisory weather and road weather information to travelers.

Table 17. State DOT Survey Question 12.1 and Associated Responses

Answer Options	#	%
Icy Roads	18	90%
Fog	14	70%
Wind	11	55%
Dust	4	20%
Snow	16	80%
Flood	13	65%
Other	2	10%
Not Sure/Unknown	0	0%
# Respondents Who Answered Question	20	

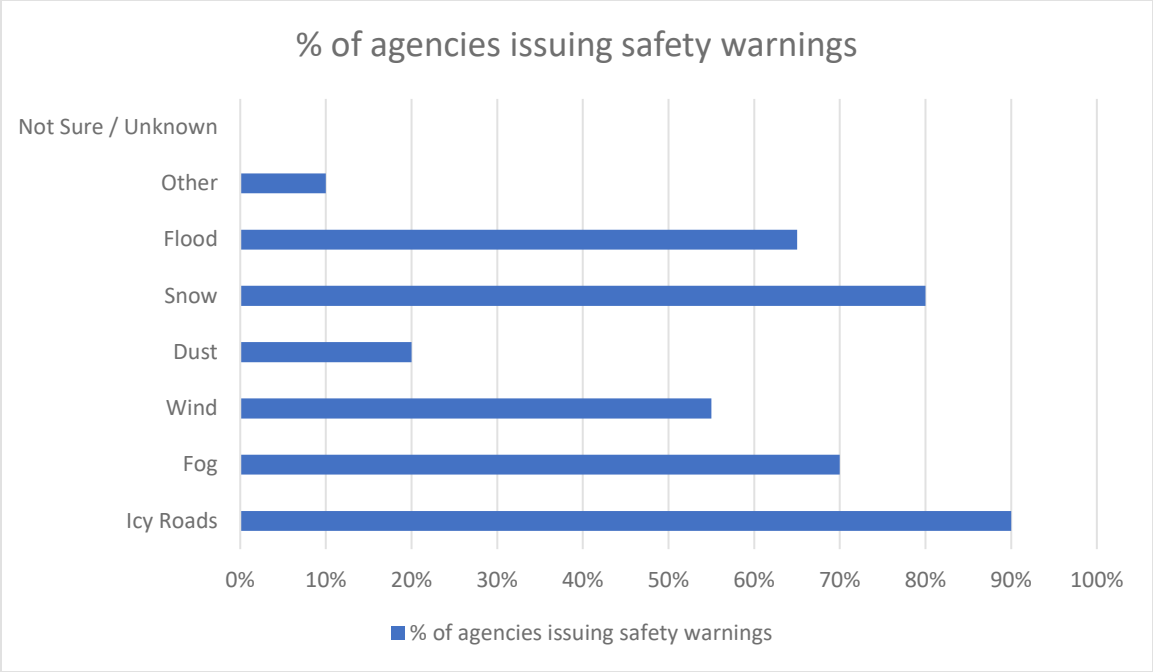


Figure 32. Graph. Responses from State department of transportation survey question 12.1

Other responses included:

- Blowing snow. We would also communicate anything else necessary using various messaging methods.
- NWS watches and warnings

Q13. Describe the level of deployment in your agency of the following weather responsive traffic management strategies. (Check all that apply):

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

Table 18. State DOT Survey Question 13 and Associated Responses

	Deployed Statewide (or in All Applicable Locations)	Limited or Partial Deployment	Not Yet Deployed	Unsure/Unknown
Ramp Meters	5.3%	15.8%	73.7%	5.3%
Traffic Signal Timing	5.1%	17.9%	71.8%	5.1%
Variable Speed Limits	2.6%	34.2%	63.2%	0.0%
Temporary Vehicle Restrictions	13.5%	24.3%	51.4%	10.8%

	Deployed Statewide (or in All Applicable Locations)	Limited or Partial Deployment	Not Yet Deployed	Unsure/Unknown
Lane/Road Closure and Traffic Diversions	32.4%	37.8%	21.6%	8.1%
Traffic Incident Management	46.2%	43.6%	5.1%	5.1%
# Respondents Who Answered Question			39	
# Respondents Who Skipped Question			0	

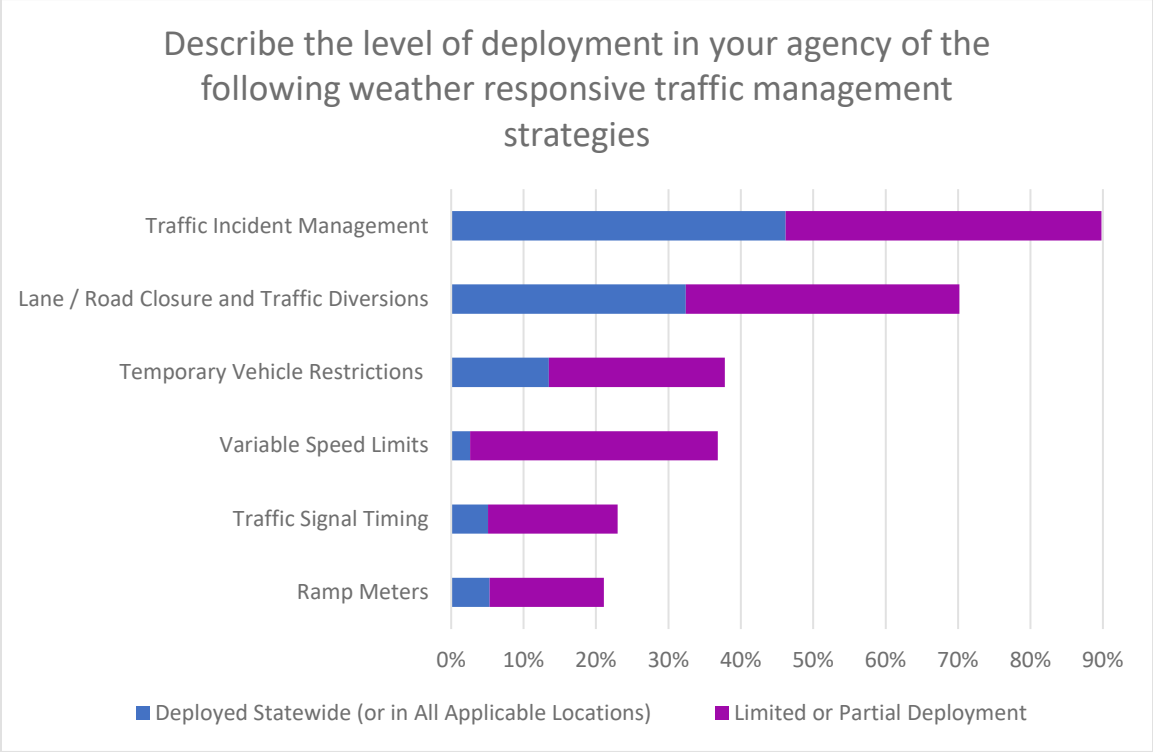


Figure 33. Graph. Responses from State department of transportation survey question 13

Q14. Describe your level of interaction with the National Weather Service local forecast offices for road weather management and operations activities.

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

Table 19. State DOT Survey Question 14 and Associated Responses

Answer Options	Percentage
Rely only on publicity available information via media and NWS, but no direct interaction or coordination	0.0%
Limited coordination and only during major weather events	7.7%
Routine coordination. Have access to meteorological expertise to assist with decision-making for most events	71.8%
Not sure/unknown	0.0%
Starting to work with local NWS offices and other weather agencies, but limited to major events	20.5%
Total	39
Number Skipped	0

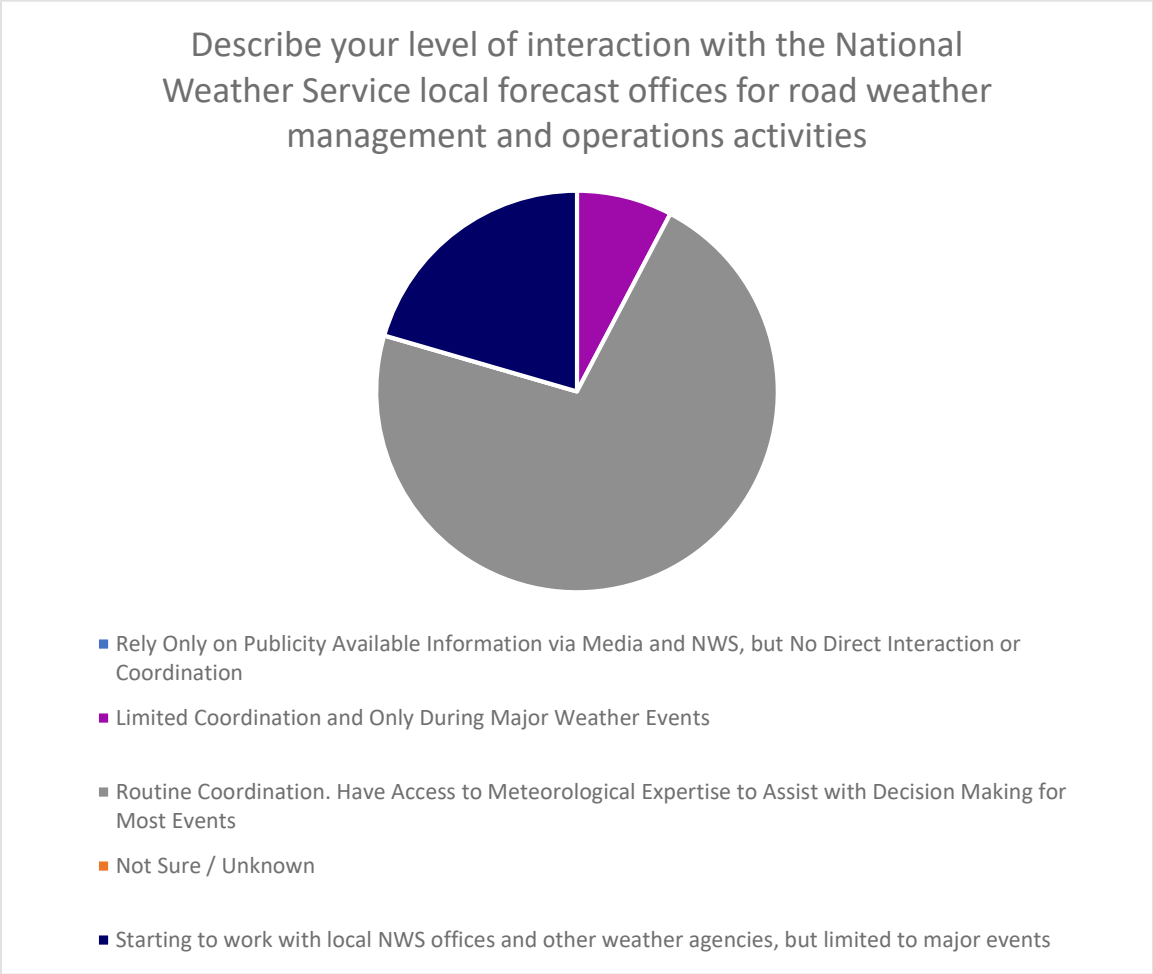


Figure 34. Chart. Responses from State department of transportation survey question 14

Q15. Does your agency use a winter Maintenance Decision Support System (MDSS) for snow and ice control? A winter MDSS includes software that proves strategic and tactical weather forecasts, supports treatment decision making and provides summary reports of weather event performance.

Related PM: Number of agencies adopting MDSS technologies and methods.

Table 20. State DOT Survey Question 15 and Associated Responses

Answer Options	Percentage
Yes – Use an MDSS Statewide	33.3%
Yes – Use an MDSS, but Not Statewide	12.8%
No – Need an MDSS, but Currently Do Not Have a System	17.9%
No – Do Not Need an MDSS	28.2%
Not Sure/Unknown	7.7%
Total	39
Number Skipped	0

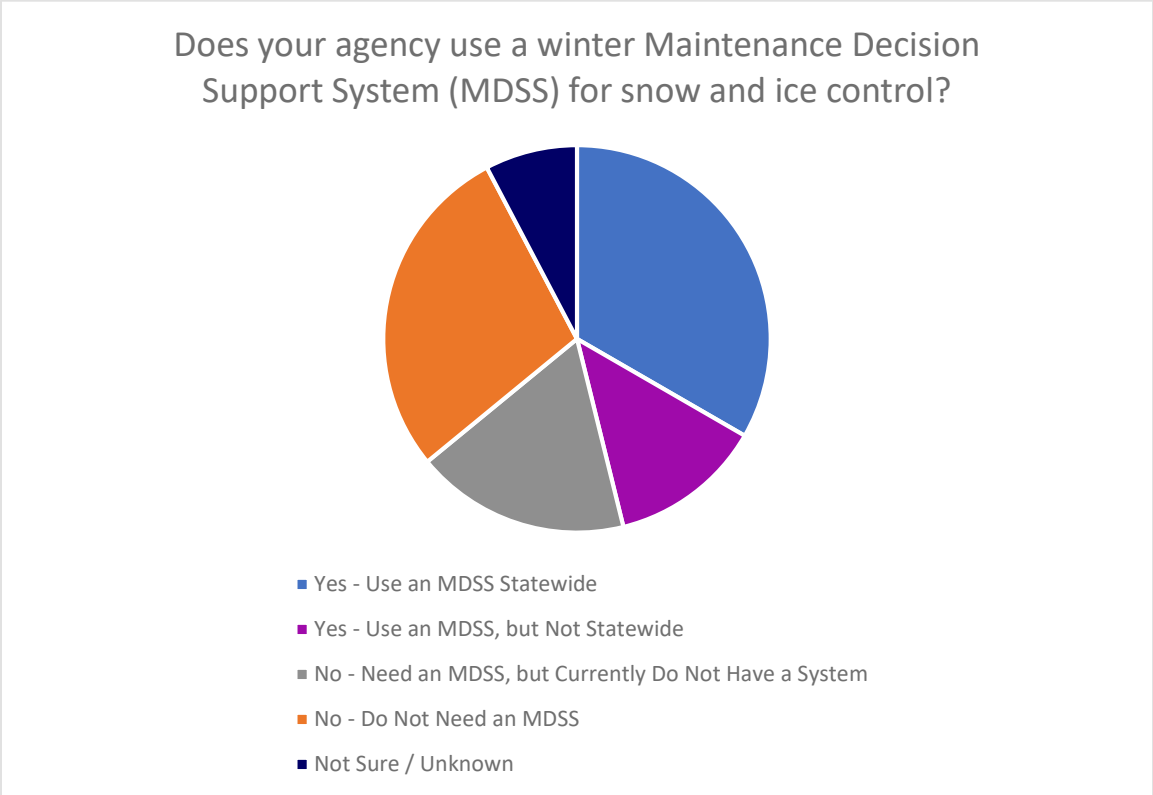


Figure 35. Chart. Responses from State department of transportation survey question 15

Q15.1. If you answered "No – need an MDSS, but currently do not have a system" to question #15, please provide the reason(s) for the lack of implementation.

Related PM: Number of agencies adopting MDSS technologies and methods.

- Currently working on getting one established; Connecticut DOT is waiting for State Administrative Services to complete pending contract with a vendor
- Lack of accurate forecast due to region of country; border cold and warm states
- Agree with the concept. Current systems do not appear to be a good match at this time. (i.e., waiting for more kinks to get worked out)
- Not enough ITS build-out
- Confidence in available off-the-shelf mobile systems
- Not sure we 100% need one but are interested in testing application
- Perceived value of MDSS doesn't equal cost to implement
- Probably due to the fact that the need is very limited. There are a couple of relatively mild winter weather events in only certain parts of Texas each year. An MDSS would be helpful but the benefit may not justify the costs. Funding

Q16. Does your agency use other decision support tools (besides a winter MDSS) for road weather management? If yes, what are these tools used for? (Check all that apply):

Related PM: Number of agencies using other weather-related decision support tools.

Table 21. State DOT Survey Question 16 and Associated Responses

Answer Options	Percentage
None	15.4%
Providing Traveler Information	61.5%
Coordination with Other Jurisdictions/Agencies	53.8%
Supporting Non-Winter Maintenance Activities (e.g., Maintenance Scheduling, Construction Coordination)	43.6%
Traffic Control and Management (e.g., Speed Limit Determination, Signal Timing Plans, Ramp Metering Rates)	25.6%
Setting Seasonal Load Restrictions	23.1%
Not Sure/Unknown	5.1%

Answer Options	Percentage
Other	7.7%
Total	39
Number Skipped	0

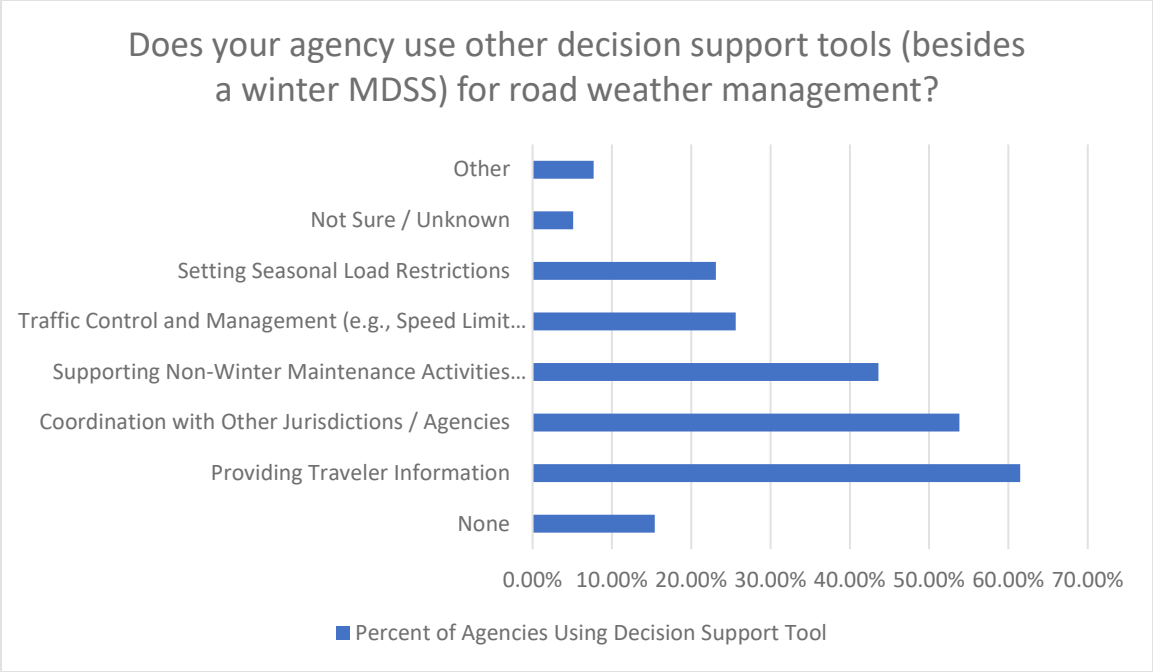


Figure 36. Graph. Responses from State department of transportation survey question 16

Other responses included:

- Flood/disaster response
- The INRIX data is impacted by weather events as vehicles slow, incidents increase, etc. Directly feeds travel times on our DMS boards, color corridor goes from green to yellow to red during (bad/extreme conditions) weather events.
- Route Optimization

Q17. What types of traffic analysis and simulation tools does your agency use for planning and evaluating road weather management strategies? (Check all that apply):

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

Table 22. State DOT Survey Question 17 and Associated Responses

Answer Options	Percentage
None	35.1%
Sketch-Planning Analysis Tools	2.7%
Travel Demand Analysis Tools	2.7%
Macroscopic Simulation Models	2.7%
Mesoscopic Simulation Models	2.7%
Microscopic Simulation Models	2.7%
Deterministic Analysis Tools (HCM-Based)	0.0%
Traffic Signal Optimization Tools	13.5%
Not Sure/Unknown	48.6%
Other	0.0%
Total	37
Number Skipped	2

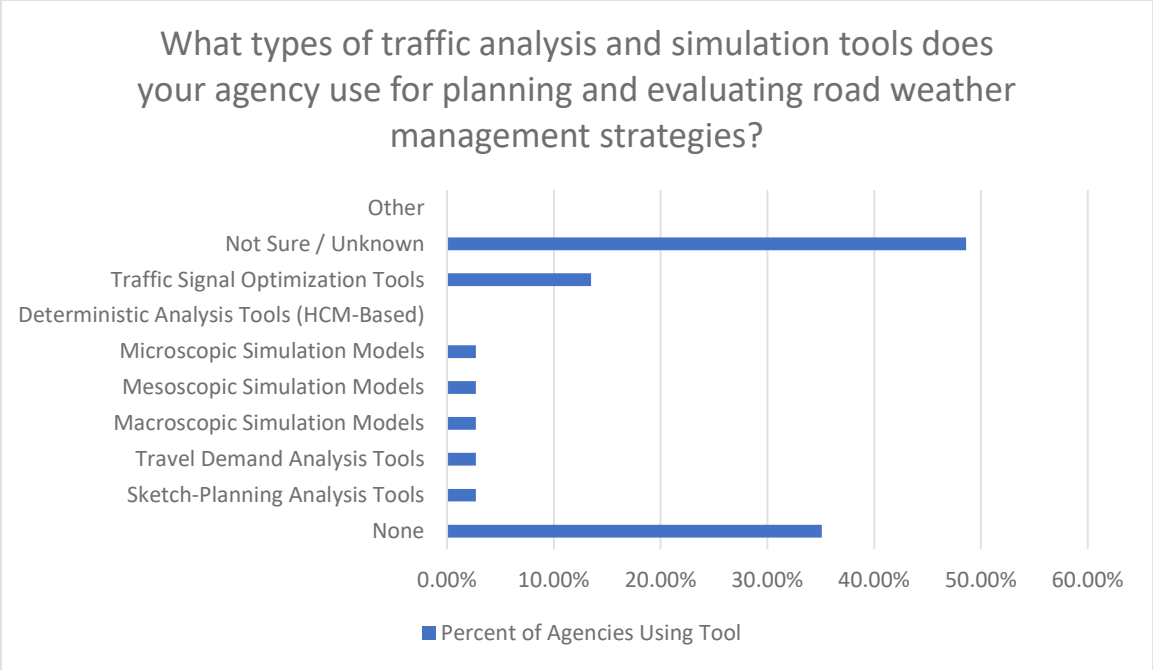


Figure 37. Graph. Responses from State department of transportation survey question 17

Q18. Has your agency (and, in particular, road weather management related staff) participated in extreme weather, transportation resilience, or climate adaptation practices/reviews?

Related PM: Number of agencies conducting vulnerability/risk assessment or developing/implementing resiliency plans, for their road weather management infrastructure and processes to respond to extreme weather.

Table 23. State DOT Survey Question 18 and Associated Responses

Answer Options	Percentage
Conducted a Vulnerability/Risk Assessment for Road Weather Management Infrastructure	25%
Developed/Implemented Process for Responding to Extreme Weather	47%
Developed/Implemented Resiliency Plans for Road Weather Management Infrastructure	28%
Participated in State DOT Resilience Adaptation Planning Activities	22%
Agency Has Not Participated in Development of Adaptation Practices	11%
Not Sure/Unknown	25%
Total	36
Number Skipped	3

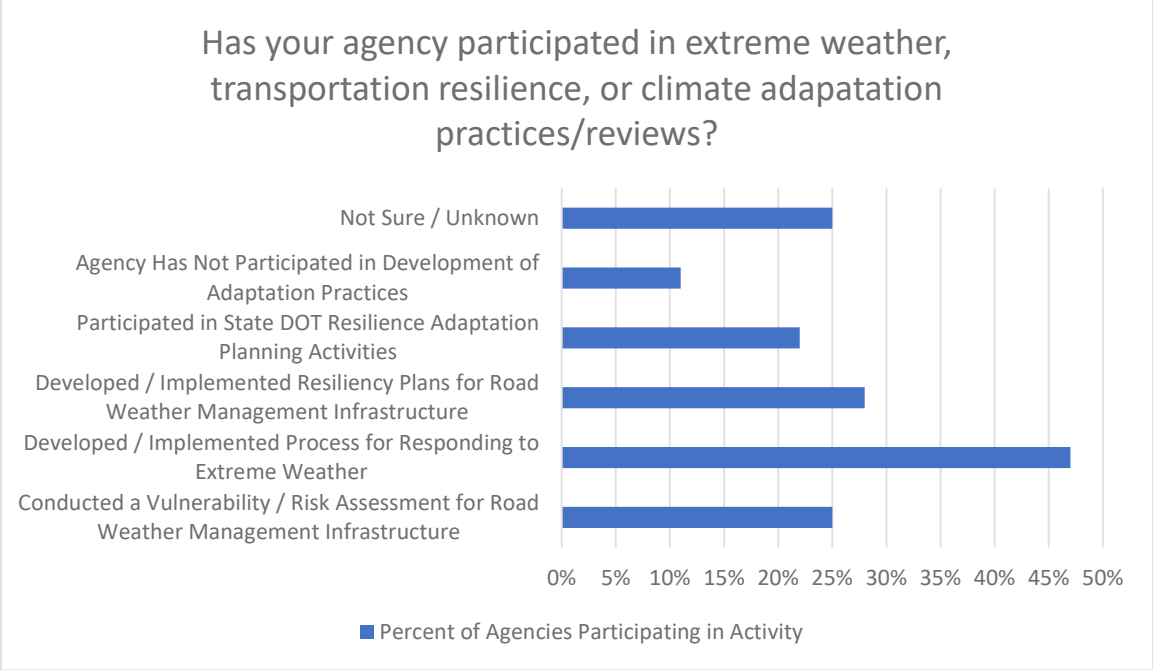


Figure 38. Graph. Responses from State department of transportation survey question 18

Q19. Would you be willing to participate in the next update of this survey?

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

Table 24. State DOT Survey Question 12 and Associated Responses

Answer Options	#	%
Yes	37	97%
No	0	0%
Not Sure/Unknown	1	3%
# Respondents Who Answered Question	38	
# Respondents Who Skipped Question	1	

Appendix B: Findings by Measure

ROAD WEATHER MANAGEMENT PROGRAM PERFORMANCE AND RESULTS

Objective 1: Build and sustain relationships with multidisciplinary partners to expand road weather management deployments.

Table 25. Summary of Objective #1 Performance Measures

PM #1: Number of agencies participating in road weather R&D projects
• 25 State DOTs are currently participating in the Pathfinder project, including 7 new States. • 15 public agencies have participated in the development and use of the Road Weather Management (RWM) Capability Maturity Framework (CMF). • 27 State DOTs have participated in the Integrated Mobile Observations (IMO) program, including 3 new States. • 21 State DOTS have participated in or contributed to weather data environment research. • There is no data on how many State DOTs have been involved in vehicle-to-infrastructure (V2I) implementation activities. • Two States currently use the Integrated Modeling for Road Condition Prediction (IMRCP) tool. • A total of 43 States are conducting at least one road weather management activity, up from 41 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 Road Weather Management stakeholder meetings increased to 29 in 2017 and 2018. • The Every Day Counts-5 (EDC-5) Summits held in 2018 were well-attended, with 48 states participating in 1 of the 5 events held around the country.

Objective 2: Ensure that road weather management investments improve highway performance.

Table 26. Summary of Objective #2 Performance Measures

PM #3: Number of agencies that collect and report road weather-related performance measures to the public (winter severity index, mobility index, etc.)
• Among the State DOTs surveyed, 24 DOTs reported regularly collecting and reporting some form of road weather performance measures. 12 DOTs reported they did not collect and report road weather performance measures, and another 3 were uncertain. This is a positive trend over the prior period in which 22 DOTs reported collecting, 13 reported not collecting, and four (4) were uncertain about collecting road weather performance measures. • 18 State DOTs reported using a winter severity index to compare agency road weather management performance across events or years. This is 2 additional agencies utilizing such a tool over the prior period.
PM #4: Number of agencies that have a process for evaluating the return on investment (ROI) or net benefit of their road weather management investments
• Only 4 State DOTs reported having a process in place to evaluate ROI or net benefits of road weather management investments, down from 9 State DOTs in the prior period.
PM #5: Reductions in agency costs of weather-related maintenance and operations activities
• While local government expenditures for snow and ice removal remained relatively constant in 2014, 2015, and 2016 (most recent data available), State government expenditures for snow and ice removal spiked by 46.7% in 2014. State government expenditures decreased in 2015 by 11.8%, but still remained above total local government expenditures. 2014 and 2015 are the first 2 years in which State government expenditures exceeded local government expenditures for snow and ice removal.[11] Total expenditures increased 24.1% from 2013 to 2014 and decreased 6.1% from 2014 to 2015. • State government expenditures for snow and ice removal decreased by 16.0% from 2015 to 2016, bringing State government expenditures below local government expenditures again. The relatively constant rate of local government expenditures means total expenditures decreased by 8.5% from 2015 to 2016. • The above observations represent the natural, unpredictable variation in weather and road weather conditions over a short observation period. A majority of States saw expenditures increase in 2014, but the most significant (over 100% increase from 2013 expenditures) were in Arkansas, Delaware, Georgia, Louisiana, Maryland, Mississippi, Missouri, North Carolina, Oklahoma, South Carolina, and Texas.

[11] Data Source: Highway Statistics (2001-2016) Data Tables SF-4C (Disbursements for State-Administered Highways) and LGF-2 (Local Government Disbursements for Highways).

- The Kentucky Transportation Center utilized GIS to optimize snowplow routes. The models were able to eliminate the need for 9 snowplows in 4 counties, which was an estimated annual $225,000 in savings.[12]

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

- The annual percentage of fatal crashes that occur during inclement weather has remained between 10% and 11% since 2005. Currently available data suggests that the annual percentage of fatal crashes occurring during inclement weather could be as low as 9%, however a number of fatal crashes remain uncharacterized in terms of weather conditions.
- The fatal crash rate during inclement weather per thousand licensed drivers peaked in 2003-2004 at 0.024 crashes per thousand licensed drivers. That rate has steadily decreased to between 0.014 and 0.016 crashes per thousand licensed drivers for the period 2009-2017.

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

- Virginia DOT implemented a variable speed limit system to combat reduced visibility associated with fog events on the I-77 corridor in Fancy Gap by reducing travel speeds on the corridor when fog was present. Prior to the installation, driver speeds remained relatively constant with non-fog conditions. After the installation, VDOT found that drivers were willing to reduce speeds to the posted level, and that the reduction in speed within the corridor did not have a significant impact on travel into or out of the corridor.[13]

PM #8: Increase in travel time reliability or decrease in variability due to road weather management strategies during adverse weather

- Few agencies currently track the impacts of road weather management strategies on travel time reliability.
- A 2018 study found that drivers were less likely to reduce their travel speed or following distance in foggy conditions compared to rainy conditions. The study suggested agencies integrate new language into dynamic messaging systems and implement variable speed limit strategies in corridors prone to fog-related accidents.[14]

[12] Blandford B, Lammers E, Green E (2018) Snow and Ice Removal Route Optimization in Kentucky. Available at: https://pubsindex.trb.org/view/2018/C/1496926

[13] Gonzales D, Fontaine M (2018) Impact of a Variable Speed Limit System on Driver Speeds During Low Visibility Conditions. Available at: https://pubsindex.trb.org/view/2018/C/1495670

[14] Peng Y, Jiang Y, Lu J, Zou Y (2018) Examining the effect of adverse weather on road transportation using weather and traffic sensors. PLoS ONE 13(10): e0205409. https://doi.org/10.1371/journal.pone.0205409

PM #9: Reduction in number of tons of salt or chemical usage in the U.S. normalized by winter severity index
• 2015 and 2016 (most recent years data is available) saw decreases in gross salt consumption over the prior year by 7% and 11%, respectively. However, the explanation of the variation may be unclear because the data is not normalized by winter severity.

Objective 3: Transportation, weather, and research communities use and rely on fixed and mobile road weather observations.

Table 27. Summary of Objective #3 Performance Measures

PM #10: Number of State DOTs participating in MADIS program
• 5 new States have a signed MADIS data sharing agreement, but 13 have dropped out of the program, according to the State DOT survey.
PM #11: Number of State DOTs that subscribe to road weather products and services
• The use of agency sensors (RWIS and IMO), agency field personnel, and the MADIS system has remained relatively constant compared to the prior period. • Significantly more states are using information from the public (including social media) and FAA products, with 29.4% and 16% increases over the prior reporting period. • Twice as many States subscribe to U.S. Geological Survey earthquake alerts than during the previous period (8 States in 2019 versus 4 States in 2017). • Use of National Weather Service products dipped 10.4% compared to the previous reporting period.
PM #12: Number of State DOTs collecting mobile observations of road weather data from vehicle fleets
• More than three-quarters of State DOTs collect mobile observations from their vehicle fleets. Of the 39 State DOTs surveyed, 30 (76.9%) reported collecting real-time field data from maintenance vehicles. This is up from 23 State DOTs from the prior period (57.5%). • Agencies reported plow status and material usage data as the most collected type of data, with 16 States reporting they collect more than 50% of their data from maintenance vehicles. 15 agencies reported more than 50% of Atmospheric Weather data and 12 agencies reported more than 50% of their Road Weather Conditions data coming from maintenance vehicles. • Compared to the 2017 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 DOTs reporting the use of Environmental Sensor Stations

(ESS) in operations and maintenance activities
• Respondents to the State DOT survey reported a total 2,610 ESS, which is an increase over previous years. • The primary use of ESS data is to support traffic management and maintenance decision-making, with over 92% of respondents indicating their agency used ESS data for this purpose. This finding is an increase over the prior period but returns to the level observed in the 2015 update. • 21 State DOTs reported using ESS data to provide current conditions to traveler information systems. This is down from 28 State DOTs that reported doing the same in the prior period. • Over the past three updates to the RWMP, there has been a downward trend in the percentage of agencies using ESS data as an input for segment-level forecasts: 2015 (57.9%); 2017 (50.0%); and 2019 (42.1%).

Objective 4: Advance the state of the art for mobile sensing and integrating vehicle data into road weather applications.

Table 28. Summary of Objective #4 Performance Measures

PM #14: Number of/percentage of responding agencies using mobile data-based applications in road weather management
• 16 State DOTs have developed applications or tools to use data generated by vehicle-to-infrastructure or infrastructure-to-vehicle connectivity. This is up from just 7 in the prior update. Another 17 State DOTs are considering, but have not yet developed, similar applications or tools.

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

Table 29. Summary of Objective #5 Performance Measures

PM #15: Number of states disseminating advisory weather and road weather information to travelers
• The percentage of agencies deploying dynamic message signs to convey atmospheric weather information has increased from 63.2% in the prior period to 71.8% in the current period. However, a smaller percentage of agencies (42.1% in prior period; 28.2% in current period) are reporting a full statewide deployment. • The percentage of agencies deploying road condition information statewide on dynamic message signs and on highway advisory radio has continually increased over the past three reporting periods, and currently sits at 59.0% and 48.7%, respectively. When

including partial deployment, these percentages rise to 97.4% and 89.7%, respectively.

- A smaller percentage of agencies are using social media to disseminate information to travelers on road weather conditions.
- The percentage of agencies disseminating road conditions via agency-hosted websites or 511 phone systems has remained relatively constant with the prior 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 89.7% of State DOTs reporting partial or statewide deployment.
- The second most common strategy is lane/road closures and traffic diversions, with 70.3% of agencies deploying partially or statewide.
- The partial or statewide deployment for temporary vehicle restrictions, variable speed limits, traffic signal timing, and ramp metering are 37.8%, 36.8%, 23.1%, and 21.1% respectively.
- A 2017 study found that signal optimization strategies at arterial-level intersections with moderate levels of demand could help reduce delay during winter weather events.[15]

PM #17: Number of agencies that coordinate with their local forecast offices for road weather management and operations

- All State DOT survey respondents reported at least some coordination with the local National Weather Service forecast office. The number of agencies reporting routine coordination with meteorological experts to provide products and information to assist in decision-making rose from 55.0% in the prior period to 71.8% in the current one. An additional 20.5% of respondents to the survey noted they were beginning to work with local NWS offices on all major events.

Objective 6: Weather-related decision support technologies are integrated into traffic operations and maintenance procedures

Table 30. Summary of Objective #6 Performance Measures

PM #18: Number of agencies adopting MDSS technologies and methods

- The percentage of State DOTs with a statewide MDSS deployment for snow and ice control increased from 20.0% in the prior reporting period to 33.3% in the current one. The percentage of State DOTs reporting a limited MDSS deployment decreased from 15.0% in the prior reporting period to 12.8% in the current one.
- The percentage of agencies that do not currently have an MDSS for snow and ice control but reported a need for one decreased from 22.5% in the prior period to 17.9% in the

[15] Lu Z, Fu L, Kwon T (2017) Effects of Winter Weather on Traffic Operations and Optimization of Signalized Intersections. Available at: https://pubsindex.trb.org/view/2017/C/1437627

current one. The percentage of agencies reporting no need for an MDSS also decreased from 35.0% in the prior update to 28.2% in the current one.

PM #19: Number of agencies using other weather-related decision support tools

- Respondents to the State DOT survey indicated an overall decrease in the use of weather-related decision support tools for road weather management, and 15.4% of States reported not using any tools.
- Providing traveler information continues to be the most-used tool; however, there is a downward trend in the percentage of agencies using this tool.
- Respondents reported using two tools, support of non-winter maintenance activities and coordination with other jurisdictions/agencies, at levels comparable to the prior update (43.6% and 53.8%, respectively).
- Respondents reported an increase in the use of decision support tools for traffic control/management and setting seasonal load restrictions.

PM #20: Number of agencies reporting use of appropriate analysis tools to factor weather impacts and strategies

- A significant majority of State DOTs responding to the survey (83.8%) reported either they did not use or were not aware of whether their agency used weather-responsive analysis tools or models. This is a decrease from the prior period, in which 95.0% of agencies reported the same.
- Traffic signal optimization tools are the most frequently used by State DOTs, with 13.5% of survey respondents indicating their agency used some form of this tool.
- Just one agency reported using sketch-planning analysis and travel demand analysis tools.
- Just one agency reported using macroscopic, mesoscopic, and microscopic simulation tools.

Objective 7: Advance the state of the practice by raising road weather capabilities and awareness across the transportation and weather community.

Table 31. Summary of Objective #7 Performance Measures

PM #21: Number of agencies and attendees who have taken any of the sponsored RWMP training courses and workshops

- The RWMP supported 26 workshops in 2017 and 28 workshops in 2018 on topics including: cost/benefit analyses; Pikalert® implementation, transportation system resilience in the context of adverse weather, weather-responsive traffic management, weather-savvy roads (EDC-4), weather-responsive management strategies (EDC-5), RWM Capability Maturity Framework, Pathfinder initiative, Integrated Mobile Observations (IMO), connected and autonomous vehicles, and business processes for

road weather operations.

PM #22: Number of agencies and participants in road weather management webinars led by the RWMP

- The RWMP supported a total of 13 webinars in 2017 and 17 webinars in 2018 on topics including: effective weather messaging, transportation system resilience in the context of adverse weather, connected and autonomous vehicles, weather-savvy roads (EDC-4), and weather-responsive management strategies (EDC-5).

PM #23: Number of agencies that have participated in or conducted road weather management capability maturity assessment exercises

- 16 States have conducted the capability maturity assessment workshops, and 4 additional States have indicated interest.

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

- Between January 2017 and March 2019, RWM program staff or support contractors attended or facilitated at least 137 conferences, meetings, peer exchanges, etc. The total number of participants at these events is estimated at over 9,400.

Objective 8: Operations community is engaged with weather resiliency and sustainability communities.

Table 32. Summary of Objective #8 Performance Measures

PM #25: Number of agencies conducting vulnerability/risk assessments or developing/implementing resiliency plans, for their RWM infrastructure and processes to respond to extreme weather

- One-quarter (25.0%) of agencies responding to the State DOT survey indicated they had conducted a vulnerability or risk assessment for RWM infrastructure. 27.8% of agencies reported developing or implementing resiliency plans for RWM infrastructure.
- Nearly half of all respondents (47.2%) reported their agency as having developed or implemented a process for responding to extreme weather.
- 22.2% of State DOTs have participated in resilience adaptation planning activities.
- Only 11.1% of agencies reported no participation in the development of adaptation practices.

U.S. Department of Transportation
Federal Highway Administration
Office of Operations
1200 New Jersey Avenue SE
Washington, DC 20590
Office of Operations Website
https://ops.fhwa.dot.gov/

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