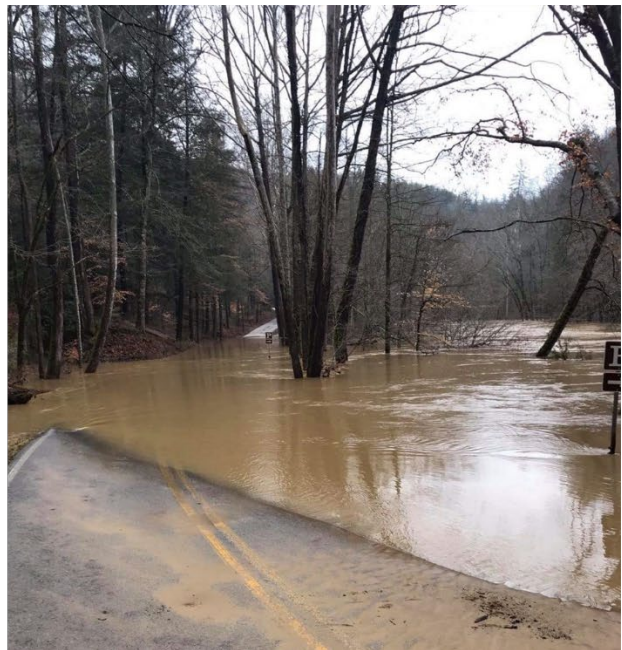# Road Weather Management Performance Measures

2021 Update

FHWA-HOP-22-002
Task 4. Final Report

U.S. Department of Transportation
Federal Highway Administration

February 2022

Cover photo: top left, Kentucky Transportation Cabinet; bottom left, Arizona Department of Transportation; right, Kentucky Transportation Cabinet

Technical Report Documentation Page

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16. Abstract Since 2006, the Federal Highway Administration (FHWA) Road Weather Management Program (RWMP) has conducted a periodic assessment of program effectiveness in improving the performance of the transportation system during adverse weather conditions. The RWMP assessments of program performance were conducted and documented in 2009, 2012, 2015, 2017, and 2019. This document is a continuation of this periodic review. It evaluates program initiatives and major accomplishments; assesses the continued suitability, strengths, and weaknesses of existing measures for evaluating program performance; and incorporates new measures, as appropriate, that reflect current and future program initiatives. The 2021 report presents the latest results of the RWMP's performance measures assessment and summarizes suggestions for the RWMP to consider related to each program objective: (1) stakeholder engagement, (2) research and development, (3) deployment, (4) knowledge and technology transfer, and (5) innovation, resilience, and sustainability.			
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List of Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ADS	Automated Driving System
AMS	American Meteorological Society
ASOS	Automated Surface Observing Systems
AV	Automated Vehicle
AVAW	Automated Vehicles and Adverse Weather
AWOS	Automated Weather Observation System.
CAV	Connected and Automated Vehicle
CITE	Consortium for Innovative Transportation Education
CMF	Capability Maturity Framework
CSO	Committee on Transportation System Operations
DMS	Dynamic Message Sign
DOT	Department of Transportation
DSRC	Dedicated Short-Range Communications
DSS	Decision Support Systems
EDC	Every Day Counts
EIPT	Environmental Information Processing Technologies
ESS	Environmental Sensor Stations
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
HAR	Highway Advisory Radio
IMO	Integrated Mobile Observations
IMRCP	Integrated Modeling for Road Condition Prediction
ITS	Intelligent Transportation Systems
ITS JPO	Intelligent Transportation Systems Joint Program Office
MADIS	Meteorological Assimilation Data Ingest System
MARWIS	Mobile Advanced Road Weather Information Sensors
MDSS	Maintenance Decision Support System
NCAR	National Center for Atmospheric Research
NCHRP	National Cooperative Highway Research Program
NHI	National Highway Institute
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
PFS	Pooled Fund Study
PM	Performance Measure
R&D	Research and Development
RWIS	Road Weather Information System
RWM	Road Weather Management
RWMP	Road Weather Management Program
SICOP	Snow and Ice Cooperative Program

TRB	Transportation Research Board
TMC	Traffic Management Center
UAS	Unmanned Aerial Systems
US	United States
USDOT	United States Department of Transportation
USGS	United States Geological Survey
V2I	Vehicle-to-Infrastructure
VMT	Vehicle Miles Traveled
WRMS	Weather Responsive Management Strategies
WSR	Weather-Savvy Roads
WxDE	Weather Data Environment

Executive Summary

Since 2006, the Federal Highway Administration (FHWA) Road Weather Management Program (RWMP) has conducted periodic assessments of program effectiveness in improving the performance of the transportation system during adverse weather conditions. The RWMP assessments of program performance were conducted and documented in 2009,[1] 2012,[2] 2015,[3] 2017,[4] and 2019.[5] These assessments reviewed initiatives and accomplishments; assessed the suitability, strengths, and weaknesses of measures for evaluating program performance; and incorporated new measures, as appropriate, that reflected current and future program initiatives. The 2021 *Road Weather Management Performance Measures Update* continues the periodic review of the RWMP's performance and updates the 2019 report.

PURPOSE OF THE REPORT

Assessing performance measures allows the RWMP to evaluate its progress and effectiveness in accomplishing its objectives. This assessment helps to communicate the areas of success of the RWMP and to identify areas that need more focus, support, and/or outreach. The 2021 report presents the latest results of the RWMP's performance measures assessment and summarizes suggestions for each program objective.

RWMP OBJECTIVES

The RWMP, to determine technical direction and activity, is guided by the following five objectives:

- **Objective 1. Stakeholder Engagement:** Build and sustain relationships with multidisciplinary partners to support and advance the road weather community.

- **Objective 2. Research and Development:** Create new and support existing research and development projects that benefit the road weather community.

- **Objective 3. Deployment:** Measure the use of road weather technology, data, and strategies.

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[1] Federal Highway Administration, *Road Weather Management Program Performance Metrics: Implementation and Assessment*. FHWA-JPO-09-061, August 31, 2009. Available at: https://rosap.ntl.bts.gov/view/dot/3993/Print.

[2] Federal Highway Administration, *Road Weather Management Performance Measures–2012 Update*. FHWA-JPO-13-87, August 6, 2013. Available at: https://rosap.ntl.bts.gov/view/dot/3409.

[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.

[5] Federal Highway Administration, *2019 Road Weather Management Performance Measures update*. FHWA-HOP-19-089, September 2019. Available at: https://ops.fhwa.dot.gov/publications/fhwahop19089/fhwahop19089.pdf.

- **Objective 4. Knowledge and Technology Transfer:** Promote, communicate, and deliver best practices for proven technology and strategies.

- **Objective 5. Innovation, Resilience, and Sustainability:** Communicate innovative solutions, recovery, standards, and data needs for road weather management.

The RWMP updated these objectives in 2021. Each of the 22 performance measures used for this assessment is assigned to 1 of these 5 objectives.

APPROACH

This update included a review of the 2019 update and of the current program objectives, activities, and products. The reporting period for the performance update was mostly January 2019 to December 2020, but some performance measures include information from before and/or after this period, depending on the availability of information. Impacts of the COVID-19 pandemic were also considered in this assessment.

The RWMP used several data sources to compose the update, including RWMP records; a survey of State DOTs conducted for this assessment; data from other Federal, State, and local agency sources and research institutions; and secondary sources to supplement the primary sources.

Twenty-two performance measures (and submeasures) were evaluated in detail, and each was assigned a summary assessment of "thumbs up," "thumbs even," or "thumbs down":

Thumbs up indicates strong performance in accomplishing the objective to which the measure maps and/or there is a strong connection between the RWMP and impacts experienced by State DOTs.

Thumbs even indicates moderate performance in accomplishing the objective to which the measure maps and/or there is a connection between the RWMP and impacts experienced by State DOTs.

Thumbs down indicates that improvements could be made to accomplish the objective to which the measure maps and consideration should be given to the likely needs identified in this report.

Likely needs are provided as suggested recommendations for the RWMP to pursue based on the findings of this assessment. However, it is expected that the RWMP will prioritize the items of greatest interest for agencies and importance to the RWMP objectives, as it is likely not realistic to pursue all activities identified herein. The assessment is described objective by objective in this report.

OBJECTIVE 1. STAKEHOLDER ENGAGEMENT

Stakeholder engagement was evaluated through stakeholder participation in FHWA-sponsored virtual events, FHWA-sponsored in-person events, and industry events where RWMP presented information about the program. The assessment showed strong performance in all measures. The results indicate that the program continues to evolve to meet the needs of State DOTs and other stakeholder partners and continues to provide relevant programming to enhance road weather management (RWM) efforts throughout the country. If the RWMP continues to work with agencies and industry stakeholders to develop programming based on feedback received from these stakeholders, and continues working with organizational and industry champions, it can maintain its momentum in reaching its objectives. Table 1 summarizes the assessment of the performance measures for stakeholder engagement.

Table 1. Stakeholder engagement assessment overview

Performance Measure	Assessment	Findings	Likely Needs for Program
1. Number of agencies participating in and benefiting from road weather management (RWM) stakeholder meetings and workshops	👍	Event participation increases year over year, indicating continued interest in Road Weather Management Program (RWMP) programming and topics by State agencies and other industry participants.	Continue to develop programming based on stakeholder needs.
2. Number of agencies and participants in RWM webinars led by the RWMP	👍	Participation levels indicate a continued interest in RWMP topical offerings and continued engagement.	Continue to work with agencies to identify topics of interest and conduct events regularly.
3. Number of meetings, site visits or venues where RWM presentations/briefings were made	👍	Consistently strong participation across industry.	Continue to keep a pulse on industry events by working with organizational champions to stay active and maintain momentum in promoting RWMP initiatives.

OBJECTIVE 2. RESEARCH AND DEVELOPMENT

RWMP performance in research and development (R&D) was assessed in terms of (1) FHWA interest and deployment of R&D projects, and (2) the level of interest in and use of connected infrastructure and connected and automated vehicles (CAVs) to support RWM practices. The assessment showed continued interest and rising participation in RWMP R&D projects, as well as strong collaboration among States and external organizations in conducting research not sponsored by the United States Department of Transportation (USDOT). Most States attributed their decision to participate in external collaborations to the influence of the RWMP. Additionally, most States noted strong interest in the use of connectivity and automation to enhance their RWM practices.

Based on the research and findings of this report, the RWMP likely needs to continue to work with agencies to push R&D projects into the mainstream to aid the evolution from research to operational practice. Another likely need is that the RWMP continue to promote research and to provide opportunities for States to participate in events in which they can learn about research projects in the road weather community.

Table 2. Research and development assessment overview

Performance Measure	Assessment	Findings	Likely Needs for Program
4. Number of agencies participating in road weather research and development (R&D) projects	👍	There is continued interest and rising participation for most R&D projects. Leveling off participation in R&D may be attributed to a move from R&D to operations.	Continue working with agencies to push projects from R&D to operations when they are ready.
5. Number of agencies researching the role of connected and automated vehicles (CAVs) in road weather management (RWM)	✊	Most States are considering use of apps to gather data through connected infrastructure and CAVs but have yet to develop them. Half of respondents have included connectivity topics and one-third have included automated driving capabilities in their strategic planning documents. Most States are interested in working with external organizations to advance connectivity and automation in RWM. Half are conducting activities to support in-vehicle RWM applications or messaging.	Considering the newness of the focus area, nurture interest through sponsored demonstrations, peer exchanges, and site visits so agencies can learn from one another. Participate in industry events when possible.
6. Number of non-United States Department of Transportation (USDOT) R&D road weather projects that State departments of transportation (DOTs) are engaged in	👍	Most States are collaborating in non-USDOT-sponsored research. Most of these States noted that their participation was influenced by Road Weather Management Program (RWMP).	Continue to promote research and to provide opportunities for States to participate in events in which they can learn about research projects in the road weather community.

OBJECTIVE 3. DEPLOYMENT

Deployment was assessed based on State agency adoption and use of road weather technology, data, and strategies. Road weather data examined include participation in the Weather Data Environment (WxDE), subscription to road weather products and services, collection of mobile

observations from vehicle fleets, use of environmental sensor stations (ESS) in operations and maintenance, and use of mobile data-based applications. Technologies and strategies assessed by RWMP include the dissemination of advisory road weather information, coordination with local National Weather Service (NWS) weather forecast offices (i.e., Pathfinder practices), and adoption of decision-support technologies and methods. The assessment found that agencies are continuing to deploy technologies, solutions, and strategies to expand their capabilities. Based on the research and finding so this report, the RWMP likely needs to continue conducting outreach to State DOT stakeholders to promote deployment and document the benefits of deploying new technologies, solutions, and strategies, particularly for agencies that may not be advancing their capabilities. This may include targeted outreach to understand the reasons for not deploying.

Table 3. Deployment assessment overview

Performance Measure	Assessment	Findings	Likely Needs for Program
7. Number of State departments of transportation (DOTs) participating in Weather Data Environment (WxDE) program	👍	Participation continues to increase.	Continue outreach to share the benefits of contribution and encourage more agency participation.
8. Number State DOTs that subscribe to road weather products and services	👍	Agency use of traditional and innovative products remains stable. There is potential for more agencies to leverage innovations for operations.	Reach out to States not using traditional products to understand why and continue outreach to promote benefits of innovative products.
9. Number of State DOTs collecting mobile observations of road weather data from vehicle fleets	👍	Number of agencies collecting real-time fleet data continues to increase, as does the collection of mobile observations by agency fleets.	Conduct outreach to agencies not collecting data to understand why and continue outreach to promote benefits of the use of mobile observation data.
10. Number of State DOTs reporting use and diversity in use of environmental sensor stations (ESS) in operations and maintenance activities	👍	The number of ESS deployed continues to increase, suggesting awareness of its value. Agency ESS use remains stable. There is potential for more agencies to leverage ESS in new ways. Segment-level forecasts may become more critical as automated vehicle (AV) use increases and operational design domains are created for weather and driving conditions. Use of ESS for segment-level forecasts may become more critical as well.	Consider reaching out to agencies with few or no ESS to provide support and to understand why they do not use ESS. Further examine how agencies are using ESS to determine whether case studies or outreach is needed to encourage use. Consider crosscutting events with automated driving system (ADS) integration research to assess the need for and role of segment-level forecasts to support ADS digital infrastructure.

Table 3. Deployment assessment overview (continuation)

Performance Measure	Assessment	Findings	Likely Needs for Program
11. Number of or percentage of responding agencies using mobile data-based applications in road weather management	👊	Agency mobile data-based application development has decreased, while interest in apps has increased, as has the number of respondents who were unsure.	Develop case studies on benefits and successful mobile data-based apps, facilitate sharing of developed apps between agencies, and/or conduct outreach to encourage agency use of apps.
12. Number of States disseminating advisory weather and road weather information to travelers	👍	Agencies continue to use many mechanisms to disseminate road weather traveler information. The number of agencies deploying safety warning systems for road weather conditions continues to increase.	Conduct outreach to encourage dissemination of more types of road weather information. Develop case studies to highlight benefits and successful safety warning systems and conduct outreach to encourage agency use of these systems.
13. Number of agencies that coordinate with their local forecast offices for road weather management and operations	👍	Significant percentage of agencies coordinate with the National Weather Service (NWS) for messaging for winter and non-winter weather events. Over half attribute this to the Road Weather Management Program (RWMP).	Continue promoting Pathfinder to States that have yet to formalize or implement it. Promote expansion of Pathfinder to additional types of events.
14. Number of agencies adopting decision support technologies and methods	👊	Agency use of decision-support systems (Statewide use, 29 percent of respondents, and not Statewide use, 17 percent of respondents) remains similar to rates in 2019 update.	Develop case studies to highlight benefits and successful decision-support systems that are being used. Conduct outreach to encourage use.

OBJECTIVE 4. KNOWLEDGE AND TECHNOLOGY TRANSFER

Under this assessment, the RWMP's success at conducting knowledge and technology transfer is focused on the level of participation in FHWA-sponsored external trainings, and capability assessments, along with how well the RWMP activities align with advancements and trends in RWM in the next 5 to 10 years. The evaluation showed that there is continued interest across State DOTs in assessing their road weather programs. It also showed that the RWMP activities largely align with advances and trends in industry. However, the RWMP should work with State agencies and research institutions to enable more discussion and understanding of the advances and trends which are newer, with less real-world application. External trainings did not occur under this reporting period due to the course content requiring significant updates (resulting in the course not being offered). A likely need for the RWMP is to continue conducting outreach to

promote the RWM Capability Maturity Framework (CMF), as well as the updated training (once it becomes available). The RWMP likely needs to maintain their focus on data use, collaboration, and severe weather. The RWMP should also work with organizations to identify deployments related to automated decision making and vehicle automation to enable more discussion and a better understanding of those two focus areas.

Table 4. Knowledge and technology transfer overview

Performance Measure	Assessment	Findings	Likely Needs for Program
15. Number of agencies and attendees who have taken any Road Weather Management Program (RWMP)-sponsored training course or workshop	👎	No external training occurred during this reporting period. Training courses are being updated and were unavailable.	Conduct broad outreach to raise awareness of web-based training when the updates are complete.
16. Number of agencies that conduct periodic assessments of road weather management (RWM) capabilities or performance	👍	There is continued interest in conducting assessments of State department of transportation (DOT) road weather programs.	Continue to promote updated Capability Maturity Framework (CMF).
17. Number of RWM meetings and webinars that include topics specific to each of the program focus areas and trends	👍	Findings were mixed, depending on topic area: data collection and use was expanded, and collaboration and severe weather events were broadly covered in RWMP activities. Automated decision making was often discussed but not always prioritized. There was a lack of focus for vehicle automation in general.	For topics covered broadly, continue to plan for and conduct events as has been done in the past. For others, work with agencies and research institutions to identify deployment cases to enable more discussion and better understanding of the topic.

OBJECTIVE 5. INNOVATION, RESILIENCE, AND SUSTAINABILITY

The degree to which the RWMP successfully promotes innovation, resilience, and sustainability was assessed based on State agency adoption and use of new and innovative approaches to road weather management, as well as the planning and preparation that States have implemented to improve resilience and sustainability. While other factors beyond RWMP activities influence State agency initiatives in this area, this assessment assumes that RWMP activities are a contributing factor to the identified performance measures. Performance measures in this category rely largely on survey responses and data from other national sources. Two

performance measures (reduction in fatal or serious crashes, and reduction in salt use) have contributing factors beyond those that the RWMP can influence—such as the severity of the winter season. For these measures, external data from national sources was incorporated to the extent possible, as was done in previous years' assessments. The assessment showed positive impacts regarding promoting innovation. The assessment of resilience and sustainability found mixed messages about agency adoption, with survey responses suggesting the responders may not be aware of their agencies' activities. A likely need for the RWMP is that the promotion of innovation continue as-is, and that the RWMP communicate with agencies to understand whether resilience and sustainability should remain focus areas.

Table 5. Innovation, resiliency, and sustainability overview

Performance Measure	Assessment	Findings	Likely Needs for Program
18. Reduction in number and types of fatalities and crashes attributed to adverse weather nationally	✊	There is no data that suggests a significant change in the number of fatal crashes related to inclement weather when considering either the crash rate per billion vehicle miles traveled (VMT) or per number of licensed drivers.	The Road Weather Management Program (RWMP) should consider continuing all activities to support safety during inclement weather and road weather events. There are anecdotal reports of increased safety, and it is encouraging that fatal crashes are not increasing.
19. Reduction in number of tons of salt or chemical usage in the U.S. normalized by winter severity index	👍	Salt usage remains relatively constant at the National level, suggesting that strategies for reducing salt use are not widespread enough to have an impact on overall use. Salt use varies from year to year; for example, mild winters typically cause dips in usage. Some places are taking innovative and creative approaches to reducing salt usage, which is a positive impact of the RWMP.	Consider identifying State departments of transportation (DOTs) willing to volunteer to offer their salt consumption statistics to correlate States' implementation of new snow and ice management approaches with a reduction in salt usage. Consider outreach that enables agencies with salt-reduction approaches to share their approaches with other States. Track actual salt use by agencies adopting these approaches in future performance management assessments.

Table 5. Innovation, resiliency, and sustainability overview (continuation)

Performance Measure	Assessment	Findings	Likely Needs for Program
20. Diversity of traffic control and road treatment strategies used by agencies during weather events	👍	Use of diverse traffic control and road treatment strategies during inclement weather is strong.	Continue outreach, with minor changes, such as allowing agencies that use intelligent transportation systems (ITS) to determine vehicle restrictions to demonstrate these systems to other States; working with traffic engineering groups to expand the use of traffic management approaches to respond to weather events; determining route selection or chemical application rates; and using unmanned aerial systems (UAS)—that is, drones.
21. Number of agencies reporting use of appropriate analysis tools to factor weather impacts and strategies	✊	Use of real-time tools for roadway maintenance is widespread. Agencies reported moderate use of real-time traffic control or management and post-event analysis. There was limited use of tools for the prediction of impacts of road weather management (RWM) strategies.	Consider additional outreach on real-time traffic control and post-event analyses. Consider increasing activities to help agencies understand the existence of tools for predicting impacts of RWM strategies and encourage use, if appropriate.

Table 5. Innovation, resiliency, and sustainability overview (continuation)

Performance Measure	Assessment	Findings	Likely Needs for Program
22. Number of agencies conducting vulnerability risk assessment or developing or implementing resiliency plans, for their RWM infrastructure and processes to respond to climate change and extreme weather	✊	There was little to no change in agency responses to participation in climate change adaptation planning and preparation of extreme weather response processes compared to the 2019 survey. Responses about extreme weather participation reflect that more than half of responders (57 percent) indicated they have participated in extreme weather response planning. But individual agency responses were inconsistent from the 2019 to 2021 survey (e.g., some agencies that reported they had participated in climate change activities in 2019 reported they had not in 2021), suggesting that knowledge of these activities by the people responding to the surveys varies from year to year. Responses indicated that participation in vulnerability risk assessments and resilience planning for RWM is low, with less than 20 percent of responders indicating participation.	Consider reintroducing the benefits of extreme weather planning and climate change adaptation planning. Consider encouraging vulnerability and resilience actions to increase participation by agencies

CONCLUSIONS

The 2021 performance measures assessment indicated strong performance by the RWMP in accomplishing the objectives of the program. Although analysis of specific performance measures revealed some topics that the RWMP could emphasize more, the findings point to the broad success of the RWMP. The primary likely need for the RWMP is therefore to continue outreach to and engagement with State DOTs, because outreach and engagement have proven successful in advancing RWMP objectives. The RWMP may also use the findings of this analysis to identify and prioritize the areas and topics to highlight or emphasize in future outreach and engagement efforts.

An additional likely need is to reexamine efforts related to Innovation, Resilience, and Sustainability (Objective 5). Although innovation-related topics showed positive program impacts, resilience and sustainability did not score so highly. A likely need is therefore that the

RWMP reach out to agencies to understand whether resilience and sustainability should continue to be focus areas for the program, and if so, which new outreach and engagement activities could be conducted in these areas.

This 2021 update also includes many tactical likely needs to promote growth in areas with weaker performance. These likely needs are intended to be constructive and comprehensive, but at the same time, RWMP is unlikely to be able to pursue all the activities identified as likely needs. The RWMP will still have to decide which actions are of greatest interest to State agencies and of greatest relevance to RWMP objectives.

1. Introduction

Since 2006, the Federal Highway Administration (FHWA) Road Weather Management Program (RWMP) has conducted a periodic assessment of program effectiveness in improving the performance of the transportation system during adverse weather conditions. Assessments of program performance were conducted and documented in 2009,[6] 2012,[7] 2015,[8] 2017,[9] and 2019.[10] These updates reviewed program initiatives and major accomplishments; assessed the continued suitability, strengths, and weaknesses of existing measures for evaluating program performance; and incorporated new measures, as appropriate, that reflected current and future program initiatives. The *2021 Road Weather Management Performance Measures Update* continues the periodic review of the RWMP's performance and updates the 2019 report. The reporting period for the performance update was mostly January 2019 to December 2020, but some performance measures include information from before and/or after this period, depending on the availability of information. Impacts of the COVID-19 pandemic were also considered in this assessment.

PURPOSE OF REPORT

The performance measures update allows the RWMP to evaluate its progress and effectiveness in accomplishing its goals and to assess the United States' capability with respect to road weather management (RWM). This assessment helps to communicate the success of the RWMP and to identify areas that need more focus, support, and/or outreach. The 2021 report presents the latest results of the RWMP's performance measures assessment and summarizes likely needs for the RWMP to consider related to each program objective. Note that it is expected that the RWMP will prioritize the likely needs of greatest interest for agencies and importance to the RWMP objectives, as it is not realistic to pursue all activities identified herein.

RWMP OBJECTIVES, MEASURES, AND FOCUS AREAS

The RWMP strives to understand how weather impacts roads and roadway safety and seeks to promote successful strategies and tools to mitigate those impacts. The program is guided by

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[6] Federal Highway Administration, *Road Weather Management Program Performance Metrics: Implementation and Assessment*. FHWA-JPO-09-061, August 31, 2009. Available at: https://rosap.ntl.bts.gov/view/dot/3993/Print.

[7] Federal Highway Administration, *Road Weather Management Performance Measures–2012 Update*. FHWA-JPO-13-87, August 6, 2013. Available
   at: https://rosap.ntl.bts.gov/view/dot/3409.

[8] 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.

[9] 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.

[10] Federal Highway Administration, *2019 Road Weather Management Performance Measures update*. FHWA-HOP-19-089, September 2019. Available at: https://ops.fhwa.dot.gov/publications/fhwahop19089/fhwahop19089.pdf.

objectives that help to determine technical direction and activity. These objectives are regularly reviewed and updated, most recently in 2021, and are as follows:

- **Objective 1. Stakeholder Engagement:** Build and sustain relationships with multidisciplinary partners to support and advance the road weather community.

- **Objective 2. Research and Development:** Create new and support existing research and development projects that benefit the road weather community.

- **Objective 3. Deployment:** Measure the use of road weather technology, data, and strategies.

- **Objective 4. Knowledge and Technology Transfer:** Promote, communicate, and deliver best practices for proven technology and strategies.

- **Objective 5. Innovation, Resilience and Sustainability:** Communicate innovative solutions, recovery, standards, and data needs for road weather management.

Each of the 22 performance measures used for this 2021 assessment is assigned to 1 of the 5 objectives, as shown in table 6.

The 2021 assessment also took into consideration near-term (5- to 10-year) advances and trends in RWM. Trends are key considerations because programmatic direction (and the resulting objectives and performance measures) will evolve with them. Trends and advances include:

- **Expanded data collection and use**—agency use of new or expanded data sources to enhance RWM strategies and make more informed decisions. This may involve the deployment of new technologies for data collection (e.g., plow sensors), procurement of third-party data (e.g., probe data), or use of crowdsourced data from social media or citizen reporting.

- **Collaboration**—State DOT use of strategies that increase DOT collaboration with other entities, such as the National Weather Service (NWS), neighboring State DOTs, local agencies, and other transportation system management and operations functions in the DOT. As one example, Pathfinder is a collaborative strategy for proactive transportation system management ahead of and during adverse weather events that encourages State DOTs, NWS, and weather service contractors to share and translate weather forecasts and road conditions into consistent transportation impact messages for the public.

- **Vehicle automation**—agency use of level 1–5 automation for fleet vehicles (e.g., plows) and RWM in support of personal vehicle and commercial motor vehicle automation (e.g., road weather data and applications). This is broad because of the evolving nature of vehicle automation and may be further broken up in future updates.

- **Automated decision making**—State DOT use of the analytics involved with data processing and data fusion to automate decision-making processes and functions (e.g., road treatment location, type, and timing; variable speed limits; road closures).

- **Focus on severe weather**—the growing emphasis of FHWA and State DOT programs on severe weather besides severe winter weather. Events such as flooding, wildfires, and tropical weather, as well as their impacts (i.e., burn scars) are included.

Table 6. Road Weather Management Program performance measures by road weather management objective

No	2021 Performance Measures	1. Stakeholder Engagement	2. Research and Development	3. Deployment	4. Knowledge and Tech Transfer	5. Innovation, Resiliency, and Sustainability
1	Number of agencies participating in and benefiting from road weather management (RWM) stakeholder meetings and workshops	●				
2	Number of agencies and participants in RWM webinars led by the Road Weather Management Program (RWMP)	●				
3	Number of meetings, site visits or venues where RWM presentations and briefings were made	●				
4	Number of agencies participating in road weather research and development (R&D) projects		●			
5	Number of agencies researching the role of connected and automated vehicles in road weather management		●			
6	Number of non-United States Department of Transportation (USDOT) R&D road weather projects that State departments of transportation (DOTs) are engaged in		●			
7	Number of State DOTs participating in the Weather Data Environment (WxDE) program			●		
8	Number State DOTs that subscribe to road weather products and services			●		
9	Number of State DOTs collecting mobile observations of road weather data from vehicle fleets			●		
10	Number of State DOTs reporting use and diversity in use of environmental sensor stations (ESS) in operations and maintenance activities			●		

Table 6. Road Weather Management Program performance measures by road weather management objective (continuation)

No	2021 Performance Measures	1. Stakeholder Engagement	2. Research and Development	3. Deployment	4. Knowledge and Tech Transfer	5. Innovation, Resiliency, and Sustainability
11	Number of/percentage of responding agencies using mobile data-based applications in road weather management			●		
12	Number of States disseminating advisory weather and road weather information to travelers			●		
13	Number of agencies that coordinate with their local forecast offices for road weather management and operations			●		
14	Number of agencies adopting decision support technologies and methods			●		
15	Number of agencies and attendees who have taken any of the sponsored RWMP training courses and workshops				●	
16	Number of agencies that conduct periodic assessments of RWM capabilities or performance				●	
17	Number of RWM meetings and webinars that include topics specific to each of the program focus areas and trends				●	
18	Reduction in number and types of fatalities and crashes attributed to adverse weather nationally					●
19	Reduction in number of tons of salt or chemical usage in the US normalized by winter severity index					●

Table 6. Road Weather Management Program performance measures by road weather management objective (continuation)

No	2021 Performance Measures	1. Stakeholder Engagement	2. Research and Development	3. Deployment	4. Knowledge and Tech Transfer	5. Innovation, Resiliency, and Sustainability
20	Diversity of traffic control and road treatment strategies used by agencies during weather events					●
21	Number of agencies reporting use of appropriate analysis tools to factor weather impacts and strategies					●
22	Number of agencies conducting vulnerability risk assessment or developing and implementing resiliency plans, for their RWM infrastructure and processes to respond to climate change and extreme weather					●

APPROACH

The approach for the 2021 update included a review of the 2019 update and of the RWMP's current objectives, activities, and products. The reporting period for the performance update was mostly January 2019 to December 2020, but depending on the availability of data, some measures include data from before and after this period.

Data Sources

The following categories of sources provided data elements for the performance measures:

- **RWMP Records**. RWMP's research, training, and engagement activities are documented in its records. The data indicates the reach and impact of the RWMP.

- **State DOT survey.** A survey of State DOTs provided data on current RWM practices and capabilities around the country. The 2021 survey was completed by 41 State DOTs, which is two more than completed the 2019 update. Figure 1 shows the States that responded.

- **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) provided additional input to the performance measure update—especially information about specific case studies or evaluations of road weather management strategies.

- **Additional data sources.** Other data sources supplement the primary sources listed above to support the assessment's findings.

Figure 1. Map. The 41 States that responded to the 2021 Road Weather Management Program survey
Source: Federal Highway Administration

Assessment Rankings

To summarize the assessment findings, each measure (and submeasure) was assigned a rating of "thumbs up," "thumbs even," or "thumbs down":

👍 indicates strong performance in accomplishing the objective to which the measure maps to and/or connection between the RWMP and impacts experienced by State DOTs.

✊ indicates moderate performance in accomplishing the objective to which the measure maps and/or connection between the RWMP and impacts experienced by State DOTs.

👎 indicates improvements could be made to better accomplish the objective to which the measure maps and consideration should be given to likely needs identified in this report.

ORGANIZATION OF REPORT

This report is organized so that each chapter covers one program objective. Each chapter details assessment findings by performance measure and provides summary tables to highlight results:

- Chapter 3. Stakeholder Engagement describes recent findings related to building and sustaining relationships with multidisciplinary partners to support and advance the road weather community.

- Chapter 4. Research and Development assesses the RWMP's performance in creating new R&D projects and supporting existing R&D projects that benefit the road weather community.

- Chapter 5. Deployment reviews the RWMP's ability to lead and support the road weather community in the deployment of innovative technologies, solutions, and strategies.

- Chapter 6. Knowledge and Technology Transfer assesses the RWMP's ability to conduct knowledge and technology transfer activities to support the development and deployment of road weather solutions.

- Chapter 7. Innovation, Resilience, and Sustainability describes the RWMP's ability to promote innovation, resilience, and sustainability by communicating solutions, standards, approaches, and data needs for road weather management.

- Chapter 8. Conclusions presents takeaways from the 2021 update and summarizes likely needs for the RWMP moving forward.

The report also includes the following appendices:
- Appendix A summarizes the survey questions and State DOTs' responses.
- Appendix B includes all findings provided in the body of the report in tabular format.

2.   Stakeholder Engagement

OVERVIEW

The RWMP is focused on building and sustaining relationships with multidisciplinary partners to support and advance the work of the road weather community. For the 2021 assessment, stakeholder engagement was evaluated by quantifying stakeholder participation in FHWA-sponsored virtual events, in-person events, and industry events where RWMP presented information about the program. The assessment showed strong performance in all measures. The results indicate the program continues to evolve to meet the needs of its partners and continues to provide relevant programming to enhance RWM across the country. To address a likely need, the RWMP should continue to work with agencies and industry stakeholders to develop programming based on feedback received and continue working with organizational and industry champions to maintain momentum in reaching RWMP objectives.

Table 7. Stakeholder engagement assessment overview

Performance Measure	Rating	Findings	Likely Needs for Program
Number of agencies participating in and benefiting from road weather management (RWM) stakeholder meetings and workshops	👍	Event participation increases year-over-year, indicating continued interest in Road Weather Management Program (RWMP) programming and topics by State agencies and other industry participants.	Continue to develop programming based on stakeholder needs.
Number of agencies and participants in RWM webinars led by the RWMP	👍	Participation levels indicate a continued interest in RWMP topical offerings and continued engagement.	Continue to work with agencies to identify topics of interest and conduct events regularly.
Number of meetings, site visits or venues where RWM presentations or briefings were made	👍	Consistently strong participation across industry.	Continue to take the pulse of the industry by working with organizational champions to stay active and maintain momentum in promoting RWMP initiatives.

FINDINGS

Agency Participation in RWMP Meetings

Agency participation continues to increase year over year for the annual RWM stakeholder meeting. Forty-three States and 125 individuals participated in the 2020 meeting, compared to the 33 States and 58 individuals that participated in 2019, and the 28 States and 56 individuals in 2018. The uptick in 2020 can be attributed to the virtual engagement required by the COVID-19

pandemic. The virtual meeting enabled a significant increase in representation. Expanded organizational participation did not occur only among State agencies, but also among academia, consulting firms, Federal agencies, international participants, local agencies, and weather service providers. All stakeholders were welcome to participate, without the constraints of time or travel budgets.

This pattern can also be found when comparing the 2018 and 2020 Pathfinder Summits. The in-person meeting had 83 participants, including 32 individuals from 24 State agencies; the virtual event had 272 participants, including 67 individuals from 28 State agencies.

This significant increase in participation indicates strong continued interest in and demand for RWMP programming and topics by State agencies. This indicates that the program continues to evolve to meet the needs of its State agency partners and continues to provide relevant programming to help enhance State road weather management operations. Especially in 2020, when resources were stretched thin and staff dealt with competing priorities on their time, they continued to participate in these multi-hour events. It also shows that time and budget were probably key factors limiting attendance at in-person meetings in prior years. Figure 2 shows the consistent, strong attendance at recent road weather management meetings.
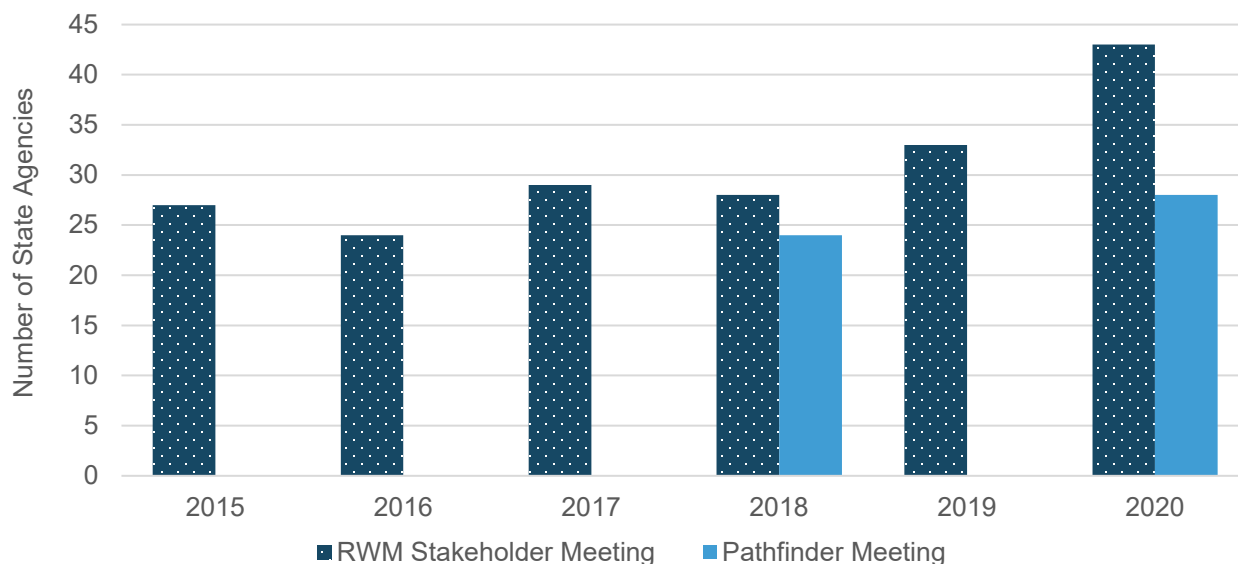
Figure 2. Graph. Number of States participating in Road Weather Management Program-sponsored meetings, 2015–2020.
Source: Federal Highway Administration

Table 8 summarizes what has been learned by assessing this performance measure, including observations and likely needs for RWMP actions.

Table 8. Assessment of performance measure 1—participation in road weather management meetings.

Overall Rating—Strong Performance				
Performance Measure (PM)	**Submeasure**	**Observations**	**Rating**	**Likely Needs for Program**
PM 1. Number of agencies participating in and benefiting from road weather management (RWM) stakeholder meetings and workshops	Participation Records	There is significant event participation that continues to increase year-over-year. This is indicative of a continued interest in Road Weather Management Program (RWMP) programming and topics by State agencies and other industry participants. These findings indicate that the program continues to evolve to meet the needs of its partners and provide relevant programming to help enhance RWM efforts across the country.	👍	Continue developing event programming based on stakeholder needs and pushing events via outreach methods such as emails, newsletters, and advertisements at industry events. Consider using virtual event tools when beneficial to participation.

Agency Participation in RWMP-Sponsored Webinars

During this evaluation period, the RWMP concentrated on promoting the Every Day Counts (EDC-5) Weather Responsive Management Strategies (WRMS) initiative. This focus on flooding preparation and management was selected because flooding has historically been an under-represented weather event in the program. Throughout the 3-part flooding webinar series—from January to September 2020—120 individuals participated in at least 1 webinar, representing 36 State agencies. Nearly half of all agencies participated in two of the three webinars, with six agencies participating in all three. Furthermore, in partnership and collaboration with other EDC-5 initiative, the RWMP cosponsored a webinar on the use of crowdsourced data for RWM. This proved very successful with 61 attendees from 33 participating State agencies.

The RWMP's regional roundtables continued to prove useful for States with consistent DOT participation between December 2019 and July 2020, with 29 and 31 State agencies represented, and 41 and 45 individuals from those agencies participating, respectively. The total number of participants in December was 90, and in July, 106. Both roundtables covered four of the five program focus areas in the 2021 evaluation: expanded data sources, collaboration, automated decision making, and severe weather events. This connection shows the relevance of these focus areas to participants, because the roundtables are an open forum for agencies to speak about their most important priorities and interests.

Table 9 summarizes what has been learned by assessing this performance measure, including observations and likely needs for RWMP actions.

Table 9. Assessment of performance measure 2—participation in Road Weather Management Program webinars

Overall Rating—Strong Performance				
Performance Measure	**Submeasure**	**Observations**	**Rating**	**Likely Needs for Program**
PM 2. Number of agencies and participants in road weather management (RWM) webinars led by the Road Weather Management Program (RWMP)	Participation Records	The level of participation for Weather Responsive Management Strategies (WRMS) webinars and the 2019 and 2020 regional roundtables indicates a continued interest in RWMP topical offerings and an interest in continued engagement among the stakeholder community with Federal Highway Administration (FHWA) acting as moderator.	👍	Continue to work with agencies to identify topics of interest and conduct webinars and other events on a regular basis to promote education and best practices as well as peer-to-peer information sharing.

Engagement with Stakeholders at Industry Events

RWM industry events contain a variety of content, topics, sponsors, and attendees. As a result, drawing conclusions from comparing one event to another is difficult. Instead, a broad idea of national interest and involvement in RWM topics is derived from reported attendance. Table 10 summarizes these events and participants. As shown by the number of activities, RWMP staff regularly participate in meetings, workshops, training, and conferences where they make presentations, briefings, and demonstrations, which extends the reach of the program beyond its own activities. For the 2-year reporting period (2019–2020), the RWMP staff and contractors attended or facilitated at least 67 conferences, meetings, or peer exchanges, reaching over 4,460 participants.

Table 10. Meetings with Road Weather Management Program representation (2019–2020)

Year	RWMP Activity	No. of Participants	No. of State Agencies
2019	American Meteorological Society (AMS) 2019 Annual Meeting	90	N/A
2019	AMS Intelligent Transportation Systems (ITS)/Surface Transportation Committee Meeting	35	3
2019	Transportation Research Board (TRB) Annual Meeting, Washington, DC	400	25
2019	TRB Committee #1	70	30
2019	TRB Committee #2	75	35
2019	Northwest Passage Pooled Fund Study	30	5
2019	American Association of State Highway and Transportation Officials (AASHTO) Committee on Transportation Systems Operations (CSO)	65	30
2019	Integrated Modeling for Road Condition Prediction (IMRCP) Stakeholder Group	17	5
2019	J2945/3 Task Force Meeting	20	5
2019	AMS ITS/Surface Transportation Committee Meeting	20	3
2019	National Weather Service (NWS) Meteorological Assimilation Data Ingest System (MADIS) Meeting	5	N/A
2019	J2945/3 Task Force Meeting	20	5
2019	AMS ITS/Surface Transportation Committee Meeting	35	3
2019	AMS ITS Mobile Observations Subcommittee	25	2
2019	Using Mobile Applications & Crowdsourced Data for Weather Responsive Management Strategies (WRMS) Joint Webinar	50	10
2019	AMS ITS/Surface Transportation Committee Meeting	35	3
2019	IMRCP Core Working Group Meeting	20	12
2019	AMS Environmental Information Processing Technologies (EIPT) Program Committee Meeting	38	N/A
2019	RWM Stakeholder Meeting	141	33
2019	J2945/3 Task Force Meeting	20	5
2019	J2945/3 Task Force Meeting	20	5
2019	Texas Short Course	20	5
2019	ITS World Congress, Special Interest Session - Advanced Weather Response Systems	150	5
2019	Aurora Fall Board Meeting	30	22
2019	AMS ITS/Surface Transportation Committee Meeting	35	3

Table 10. Meetings with Road Weather Management Program representation (2019–2020) (continuation)

Year	RWMP Activity	No. of Participants	No. of State Agencies
2019	RWM Roundtable Meetings	90	29
2019	J2945/3 Task Force Meeting	20	5
2019	Automated Vehicles and Adverse Weather (AVAW) Stakeholder Meeting	25	18
2020	TRB Annual Meeting, Washington, DC	420	25
2020	TRB Committee #1	70	30
2020	TRB Committee #2	75	35
2020	AMS ITS Mobile Observations Subcommittee	25	2
2020	AMS 2020 Annual Meeting	95	0
2020	AMS ITS/Surface Transportation Committee Meeting	42	3
2020	NWS MADIS Meeting	4	0
2020	NWS Headquarters Meeting	3	0
2020	AMS Committee on Emergency Management	22	0
2020	NWS Partner's Meeting	70	0
2020	Flood Preparation, Response, & Recovery Virtual Panel Discussion	117	33
2020	J2945/3 Task Force Meeting	20	5
2020	Aurora Board Meeting	25	10
2020	J2945/3 Task Force Meeting	20	5
2020	WRMS & Unmanned Aerial Systems (UAS) Joint Webinar	50	15
2020	Pathfinder Summit	272	28
2020	J2945/3 Task Force Meeting	20	5
2020	Analysis, Modeling, & Simulation Expert Panel Webinar	18	6
2020	TRB Road Weather Committee Meeting	30	16
2020	Federal Emergency Management Agency (FEMA) Meeting	4	0
2020	AMS ITS/Surface Transportation Committee Meeting	35	3
2020	RWM Roundtable Meetings	106	31
2020	Snow and Ice Cooperative Program (SICOP) Annual Meeting	150	30
2020	RWM Stakeholder Meeting	308	43
2020	AVAW Stakeholder Meeting	30	22
2020	California Pathfinder Meetings	15	1
2020	Wisconsin Pathfinder Meetings	30	3
2020	National Center for Atmospheric Research (NCAR) Collaboration Meeting	7	0
2020	Clear Roads Fall Meeting	30	14

Table 10. Meetings with Road Weather Management Program representation (2019–2020) (continuation)

Year	RWMP Activity	No. of Participants	No. of State Agencies
2020	AASHTO CSO Meeting	70	28
2020	WRMS Webinar - Drones	126	26
2020	Pikalert Users Group Meeting	31	17
2020	WRM Data Tools for Flood Management Webinar	112	18
2020	TRB Road Weather Committee Meeting	70	25
2020	AMS ITS/Surface Transportation Committee Meeting	35	3
2020	TRB Webinar: Finding the Path--Messaging Before, During, and After Weather Events	86	13
2020	EDC-6 Summit	100	35
2020	Indiana Pathfinder Meetings	40	3

Table 11 summarizes what has been learned by assessing this performance measure, including observations and likely needs for RWMP actions.

Table 11. Assessment of performance measure 3—engagement and public activities

Overall Rating—Strong Performance				
Performance Measure	Submeasure	Observations	Rating	Likely Needs for Program
PM 3. Number of meetings, site visits, or venues where road weather management (RWM) presentations briefings were made	Participation Records	There is consistently strong participation across the industry and by State agencies at public activities in which the Road Weather Management Program (RWMP) representatives are either attending, presenting, or moderating.	👍	Continue to take the pulse of the industry at national and international activities and events, working with organizational champions and points of contact and participating in or leading sessions at meetings, workshops, conferences, and other events to maintain momentum in promoting RWMP initiatives.

3.   Research and Development

OVERVIEW

A major focus area for the Road Weather Management Program (RWMP) is creating new Research and Development (R&D) projects and supporting existing R&D projects that benefit the road weather community. The RWMP's performance in this area was assessed by looking at both agency interest and deployment of R&D projects as well as the level of interest and use of connected infrastructure and connected and automated vehicles (CAVs) to support road weather management practices. The evaluation showed a continued interest and rising participation in the RWMP R&D projects as well as strong collaboration among States and external organizations in conducting non-United States Department of Transportation (USDOT) sponsored research. According to survey findings, most States attributed their decision to participate in these external collaborations to the influence of the RWMP. Additionally, the majority of States noted a strong interest in the use of connectivity and automation to enhance their RWM practices. To address a likely need, the RWMP should continue to work with agencies to push R&D projects into the mainstream to aid the evolution from research to operational practices. A second likely need is that the RWMP continue to promote research and to provide opportunities for States to participate in events in which they can learn about different research projects in the road weather community.

Table 12. Research and development assessment overview

Performance Measure	Assessment	Findings	Likely Needs for Program
Number of agencies participating in road weather research and development (R&D) projects	👍	Continued interest and rising participation levels for most R&D projects. Leveling off of participation may be attributed to an agency's move from R&D to operations.	Continue working with agencies to promote projects from R&D to operations.

Table 12. Research and development assessment overview (continuation)

Performance Measure	Assessment	Findings	Likely Needs for Program
Number of agencies researching the role of connected and automated vehicles (CAVs) in road weather management (RWM)	✊	Majority of States are considering use of apps to gather data via connected infrastructure and CAVs but have yet to develop them. Half of respondents have included connectivity topics and one third have included automated driving capabilities in their strategic planning documents. Most States are interested in working with external organizations to advance connectivity and automation in RWM. Half are conducting activities to support in-vehicle RWM applications or messaging.	Given newness of focus area, nurture interest through sponsored demonstrations, peer exchanges, and site visits so agencies can learn from one another. Participate in industry events when possible.
Number of non-United States Department of Transportation (USDOT) R&D road weather projects that State departments of transportation (DOTs) are engaged in	👍	Majority of States are collaborating in non-USDOT sponsored research. Most of these States noted their participation was influenced by RWMP.	Continue to promote research and to provide opportunities for States to participate in events in which they can learn about different research projects in the road weather community.

FINDINGS

Agency Participation in Road Weather Research and Development Projects

To help advance road weather R&D projects, the RWMP partners with State and local transportation agencies in support of these efforts. In recent years, the program's focus has included: the Pathfinder Initiative and Integrated Mobile Observations (IMO) Program (both under the EDC-4 Weather-Savvy Roads (WSR) initiative),[11] along with the EDC-5 Weather Responsive Management Strategies (WRMS) initiative,[12] and the Weather Data Environment (WxDE).[13]

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[11] More information available at: https://www.fhwa.dot.gov/innovation/pdfs/factsheets/edc/weather_savvy_roads.pdf.
[12] More information available at: https://www.fhwa.dot.gov/innovation/everydaycounts/edc_5/docs/wrm-factsheet.pdf.
[13] More information available at: https://wxde.fhwa.dot.gov.

The number of agencies using Pathfinder, WRMS, and WxDE continues to trend upward while the number of agencies using IMO appears to be leveling off. Figure 3 shows the breakdown.
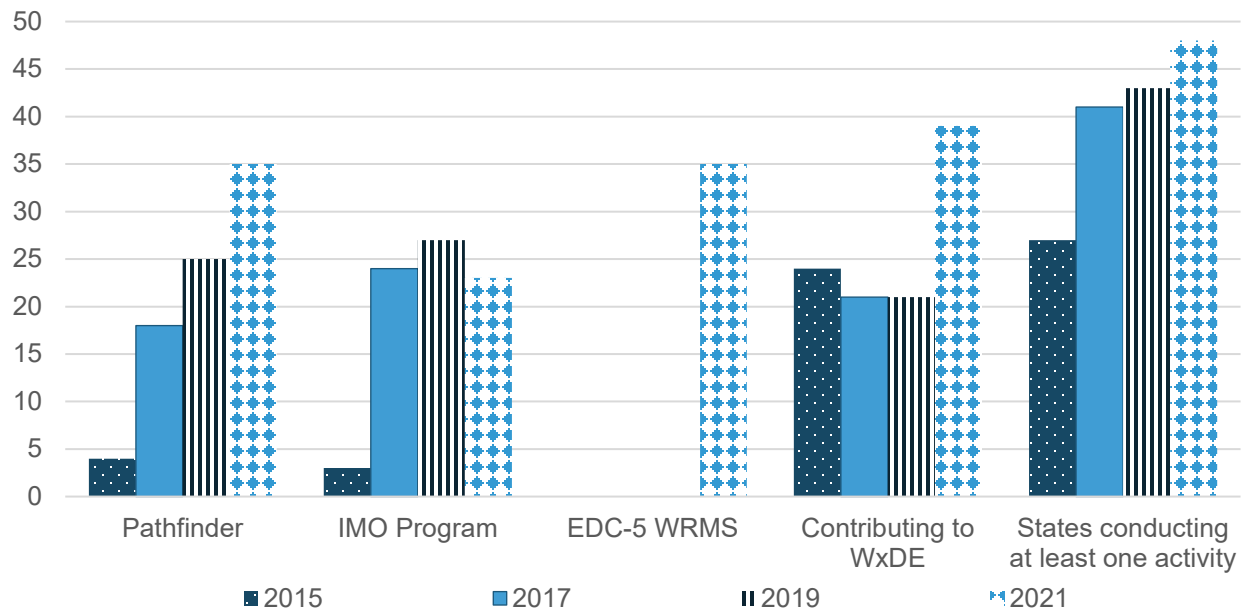
Figure 3. Graph. Number of agencies participating in road weather research-and-development projects, 2015–2021
Source: Federal Highway Administration

This leveling off of IMO may be related to the project becoming more mainstream—or institutionalized—agency operations. For many States, IMO may have also transitioned into WRMS (following the shift from EDC-4 to EDC-5), which could also explain the trending numbers. The large uptick in WxDE can be attributed to the recent renewed focus on WxDE and subsequent outreach activities conducted by the RWMP. Last, the increase in Pathfinder is expected, because it continues to be of interest for many departments of transportation (DOTs) and their external partners. The increase in severe weather events in recent years may also help to explain the increasing need for collaboration. Nearly every State is conducting at least one activity. This uptick is indicative of the success of the RWMP's efforts in promoting these projects. Given the high level of participation, the RWMP should continue to focus on transitioning these projects from R&D to mainstream operations to the extent possible.

Table 13 summarizes what has been learned by assessing this performance measure, including observations and likely needs for RWMP actions.

Table 13. Assessment of performance measure 4—participation in research and development projects.

Overall Rating—Strong Performance			
Submeasure	**Observations**	**Rating**	**Likely Needs for Program**
Participation Records	There is continued interest and rising participation for most of the research and development (R&D) projects examined (e.g., Pathfinder, Weather Responsive Management Strategies (WRMS), Weather Data Environment (WxDE)). For Integrating Mobile Observations (IMO), leveling off of participation may be attributed to mobile observations becoming mainstream in agency operations.	👍	Continue to work with agencies to push projects into the mainstream.

The Role of Connected and Automated Vehicles in Agency Road Weather Management

With increasing focus on the use of CAVs across the transportation landscape, the 2021 RWMP performance measures update included a new measure to assess the number of agencies researching the role of CAVs in RWM. This measure was assessed through several survey questions. Responses indicated growing interest in connectivity and CAV.

Agency applications and tools using real-time mobile data from connected infrastructure and/or CAVs. When asked whether their agency had developed applications or tools that use mobile data from agency fleet vehicles and/or vehicle-to-infrastructure (V2I) connectivity for RWM, 53 percent (21 States) noted that their agencies were considering applications but had not yet developed them, while 33 percent (13 States) said they had developed applications. The remaining 15 percent (6 States) were unaware of whether anything had been considered or developed.

Agency strategic plans incorporating connected infrastructure and automated driving for RWM. V2I connectivity has the potential to support mobile road weather data collection and the communication of that data to a DOT for processing. Similarly, it can support the communication of data from a DOT to a vehicle for use by a driver or in-vehicle application. Given these potential opportunities, participants were asked whether their agency developed or is developing a strategic plan (or similar documentation) that includes CAVs:

- **Connectivity**. Thirty-six percent of responses noted that agency documentation addresses the use of V2I and agency fleet vehicles, while 17 percent noted that agency documentation addresses the use of V2I and private vehicles. Twelve percent of responses indicated

agencies do not have any document addressing connectivity, while 10 percent are unsure what is being done.

- **Automated driving**. Thirty percent of responses were unsure of whether information about automated driving is included in any documentation. Of those that were aware of the status of their documents, 33 percent indicated that agencies have no documentation in place for automated driving capabilities. Twenty-two percent noted that documentation addresses the role of partially or fully automated driving capabilities in agency fleet vehicles while 15 percent indicated the same for private vehicles.

Agency organizational participation in road weather and CAV discussions. Participants were asked whether their agencies have participated in organizational discussions (i.e., associations, working groups, pooled-fund studies) about RWM and the role of CAVs. Forty-four percent of responses indicated organizational discussions about connected vehicles had taken place, and 38 percent noted discussions about partially or fully automated driving capabilities. Eleven percent were unsure of whether discussions had occurred between their agency and related organizations, and 6 percent noted no discussions were held about these topics.

Agency activities supporting CAV capabilities for RWM. When asked if an agency had conducted or is conducting research projects, demonstrations, tests, or deployments using infrastructure to broadcast information to support in-vehicle RWM applications or messaging, 48 percent (19 States) said yes, 30 percent (12 States) said no, and the remaining 23 percent (9 States) were unsure.

These survey results indicate there is growing interest in the use of CAVs for RWM, but given the newness of the technology, the evolving landscape, the policy implications, and budget constraints, many agencies—although interested—are only in the early stages of potential use or application. For example, although 25 States noted their intentions to use V2I in their strategic planning documents, only 19 States are conducting research, demonstrations, tests, or deployments of applications. The CAV field will undoubtedly advance in the next few years. R&D projects such as IMO, WRMS, and WxDE, and the significant outreach and engagement that RWMP conducts lead to an expectation that during the next performance measure assessment update States will provide significant updates in this area.

Table 14 summarizes what has been learned by assessing this performance measure, including observations and likely needs for RWMP actions.

Table 14. Assessment of performance measure 5—agency assessment of the role of connected and automated vehicles in road weather management

Overall Rating: Moderate Performance			
Submeasure	**Observations**	**Rating**	Likely Needs for Program
Use of Applications and Tools	The majority of States surveyed are considering the use of apps/tools to gather and use mobile road weather data from infrastructure and/or connected and automated vehicles (CAVs) but have yet to develop them. While a third of States surveyed have developed them, 15 percent of States are unsure of the status of any such tool.	👊	Given the newness of this focus area, it is encouraging to see so much interest. The Road Weather Management Program (RWMP) should nurture this interest through demonstrations, peer exchanges, and site visits in which agencies can learn from each other, sharing ideas and lessons learned. Case studies and fact sheets should be developed to aid agencies in understanding not only how to implement but also the related benefits and costs to help "make the case" to leadership and gain the necessary buy-in.
Strategic Planning Documents	Roughly half of all responses indicate vehicle-to-infrastructure (V2I) connectivity is included in planning documents while the remaining half either do not have any documentation or are unsure of the status. One-third of responses noted the inclusion of automated driving capabilities in documentation, one-third noted no documentation, and the remaining third are unsure of the status.	👊	Given the newness of this focus area, it is important for the RWMP to provide learning opportunities and ways for early adopters to work with interested parties to understand how connectivity and automated driving capabilities can support road weather management (RWM).
Organizational Participation	The majority of responses indicate agencies are interested in talking with external organizations about the use of connected vehicles, automated driving capabilities, or both to support RWM.	👍	To support external discussions, the RWMP should continue to participate in or facilitate sessions at industry events. This will enable the RWMP to not only stay up to date on what is happening throughout the country but also to help guide developments and provide technical assistance.

Table 14. Assessment of performance measure 5—agency assessment of the role of connected and automated vehicles in road weather management (continuation)

Overall Rating: Moderate Performance			
Submeasure	**Observations**	**Rating**	**Likely Needs for Program**
Agency Research, Demonstrations, Tests, Deployments	Nearly half of respondents indicated they are conducting activities that support the use of infrastructure to broadcast information to support in-vehicle RWM applications or messaging. About a quarter said they are not doing anything, and the rest are unsure.	✊	The RWMP should continue to provide support, such as technical assistance, grants, and informational materials to agencies interested in pursuing connected and automated vehicle (CAV) activities to enhance RWM practices. This may include working with other groups such as the United States Department of Transportation (USDOT) Intelligent Transportation Systems Joint Program Office.

Agency Participation in non-U.S. Department of Transportation–sponsored Research and Development

To understand how the RWMP influences road weather research, the 2021 update incorporated a new measure that evaluated the level of participation in non-USDOT-sponsored research and whether that research can be attributed to the RWMP's influence. The results, gathered through survey questions, indicate that most States participate in non-USDOT-sponsored research and have done so because of the RWMP.

Participation in non-Federally sponsored collaboration or research. Participants were asked whether their agencies are collaborating with other groups in non-USDOT-sponsored research. Most States (60 percent or 24 States) responded yes. Only nine States answered no, and seven States said they were unsure of whether collaboration was occurring. When asked for further information about the collaboration occurring, respondents gave the following answers: the Aurora Pooled Fund Study (PFS), the Clear Roads PFS, the Enterprise PFS, the Maintenance Decision Support System (MDSS) PFS, the North/West Passage PFS, the National Cooperative Highway Research Program (NCHRP), the Traffic Management Center (TMC) PFS, the Western States Rural Transportation Consortium and other multi-State projects.

Influence of the RWMP. The survey asked participants if their participation in non-sponsored research is influenced by the RWMP. Nearly 70 percent (28 States) answered yes, with only 5 percent (2 States) saying no and 25 percent (11) States saying they were not sure of the influence. When asked for which programs the RWMP had influenced participation, respondents answered: Pathfinder (7 States), MDSS (6 States), IMO (3 States), EDC-5 WRMS (2 States), and EDC-4 WSR (2 States). Other answers included technology implementation (2 States), guidance and best practices (2 States), research and partnerships (1 State), dedicated short-range communications (DSRC) assessment (1 State), Road Weather Information Systems (RWIS) (1 State), Mobile Advanced Road Weather Information Sensors (MARWIS) (1 State), and standardized message boards (1 State).

Table 15 summarizes what has been learned by assessing this performance measure, including observations and likely needs for RWMP actions.

Table 15. Assessment of performance measure 6—participation in non-U.S. Department of Transportation–sponsored research and development

Overall Rating—Strong Performance			
Submeasure	**Observations**	**Rating**	**Likely Needs for Program**
Participation in Non-Federally Sponsored Research	Most States responded that they are collaborating with other groups in non-United States Department of Transportation (USDOT)-sponsored research with a multitude of pooled fund study (PFS) and other consortium opportunities listed.	👍	Continue to provide opportunities for the road weather industry to come together (e.g., national stakeholder meetings) to enable open discussions, networking, and learning opportunities so States can continue to identify different opportunities for collaborative partnerships and related programming.
Influence of the Road Weather Management Program (RWMP)	The majority of States participating in non-sponsored research noted that the RWMP influenced their decision to do so.	👍	Continue to promote research and to provide opportunities for States to participate in events in which they can learn about different research projects in the road weather community.

4.   Deployment

OVERVIEW

The Road Weather Management Program (RWMP's) mission is to lead and support the road weather community in the development and deployment of innovative technologies, solutions, and strategies. For this report, the assessment of deployment was based on State agency adoption and use of road weather technology, data, and strategies. Agencies' participation in the Weather Data Environment (WxDE), their subscription to road weather products and services, collection of mobile observations from vehicle fleets, use of environmental sensor stations (ESS) in operations and maintenance, and use of mobile data-based applications were assessed. Examples of technologies and strategies assessed include the dissemination of advisory road weather information, coordination with National Weather Service (NWS) forecasting offices, and adoption of decision-support technologies and methods. The assessment found that agencies continue to deploy technologies, solutions, and strategies to expand their capabilities. To address a likely need, the RWMP should continue conducting outreach activities to promote deployment and document benefits of deploying new technologies, solutions, and strategies, particularly for agencies that may not be advancing their capabilities. This may include some targeted outreach to understand the reasons for not deploying.

Table 16. Deployment assessment overview

Performance Measure	Assessment	Findings	Likely Needs for Program
Number of State departments of transportation (DOTs) participating in Weather Data Environment (WxDE) program	👍	Participation continues to increase.	Continue outreach to share benefits of contribution and encourage more agency participation.
Number State DOTs that subscribe to road weather products and services	👍	Agency use of traditional and innovative products remains stable. There is potential for more agencies to leverage innovations for operations.	Reach out to States not using traditional products to understand why and continue outreach efforts to promote benefits of innovative products.
Number of State DOTs collecting mobile observations of road weather data from vehicle fleets	👍	Number of agencies collecting real-time fleet data continues to increase as does the collection of mobile observations by agency fleets.	Conduct outreach to agencies not collecting data to understand why and continue outreach to promote benefits of the use of mobile observation data.

Table 16. Deployment assessment overview (continuation)

Performance Measure	Assessment	Findings	Likely Needs for Program
Number of State DOTs reporting use and diversity in use of environmental sensor stations (ESS) in operations and maintenance activities	👍	Number of deployed ESS continues to increase, suggesting agency awareness of its value. Agency ESS use remains stable. There is potential for more agencies to leverage ESS in new ways. Segment level forecasts may become more critical as Automated Vehicle (AV) use increases and operational design domains are created for weather and driving conditions. Use of ESS for segment level forecasts may become more critical as well.	Consider reaching out to agencies with few or no ESS to provide support and to understand why ESS are not deployed. Further examine how agencies are using ESS to determine whether case studies or outreach activities are needed to encourage greater agency use. Consider cross-cutting events with automated driving system (ADS) integration research to assess the need for and role of segment level forecasts to support ADS digital infrastructure.
Number of/percentage of responding agencies using mobile data-based applications in road weather management	✊	Agency mobile data-based application development has decreased, while interest in apps has increased (as well as respondents who were unsure).	Develop case studies on benefits and successful mobile data-based apps, facilitate sharing of developed apps between agencies, and/or conduct outreach activities to encourage greater agency use of apps.
Number of States disseminating advisory weather and road weather information to travelers	👍	Agencies continue to use many mechanisms to disseminate road weather traveler information. Agencies deploying safety warning systems for road weather conditions continues to increase.	Conduct outreach to encourage dissemination of more types of road weather information Statewide. Develop case studies to highlight benefits and successful safety warning systems and conduct outreach activities to encourage greater agency use of these systems.
Number of agencies that coordinate with their local forecast offices for road weather management and operations	👍	Significant percentage of agencies coordinate with the National Weather Service (NWS) for messaging for winter and non-winter weather events. Over half attribute this to the Road Weather Management Program (RWMP).	Continue promoting Pathfinder to States yet to formalize or implement it. Promote expansion of Pathfinder to additional types of events and Statewide.

Table 16. Deployment assessment overview (continuation)

Performance Measure	Assessment	Findings	Likely Needs for Program
Number of agencies adopting decision support technologies and methods	👊	Agency use of decision support systems (Statewide use, 29 percent of respondents, and not Statewide use, 17 percent of respondents) remains similar to 2019 update.	Develop case studies to highlight benefits and successful decision support systems that are being used. Conduct outreach activities to encourage greater use.

FINDINGS

Participation in the Weather Data Environment Program

Thirty-nine State agencies reported contributing to the WxDE program. This reflects a significant increase from the 21 State agencies that were contributing to the WxDE program in 2017 and 2019. This measure represents a positive trend for the RWMP, which table 1 summarizes.

Table 17. Assessment of performance measure 7—participation in Weather Data Environment

Overall Rating—Strong Performance			
Submeasure	**Observations**	**Rating**	**Likely Needs for Program**
Participation Records	Participation in the Weather Data Environment (WxDE) program has greatly increased since 2019.	👍	Continue outreach activities to share benefits of contributing to the WxDE to encourage increased agency participation.

State Subscription to Road Weather Products and Services

This performance measure examines agency subscriptions to a variety of road weather products and services to increase situational awareness for improving road weather management activities in operations and maintenance. This measure reviews State DOT subscription rates alongside other data sources to gauge the impact of the availability of data on strategic and tactical decision making.

Responses to the 2021 State DOT survey indicate high levels of subscriptions to weather and road-weather products and services that support the State 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 NWS, the Federal Aviation Administration (FAA), 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 4.

Since 2019, the number of subscribers to these services has remained relatively constant, including the subscriptions to private-sector weather service providers. However, there are a few changes in this update, summarized as follows:

- **Use of public and social media.** Significantly fewer State DOTs reported utilizing data from public and social media than in 2019, dropping back down to a similar level as reported in the 2017 update.

- **Use of FAA products.** The number of agencies using FAA products decreased from the 2019 update and returned to the level observed during the 2017 update.

- **Use of NWS products.** More State DOTs reported utilizing NWS products than in 2019, bouncing back to the level observed in the 2017 update.

- **MADIS participation.** Respondents reported lower participation in the National Oceanic and Atmospheric Administration's (NOAA's) Meteorological Assimilation Data Ingest System (MADIS), continuing a trend observed since 2015.
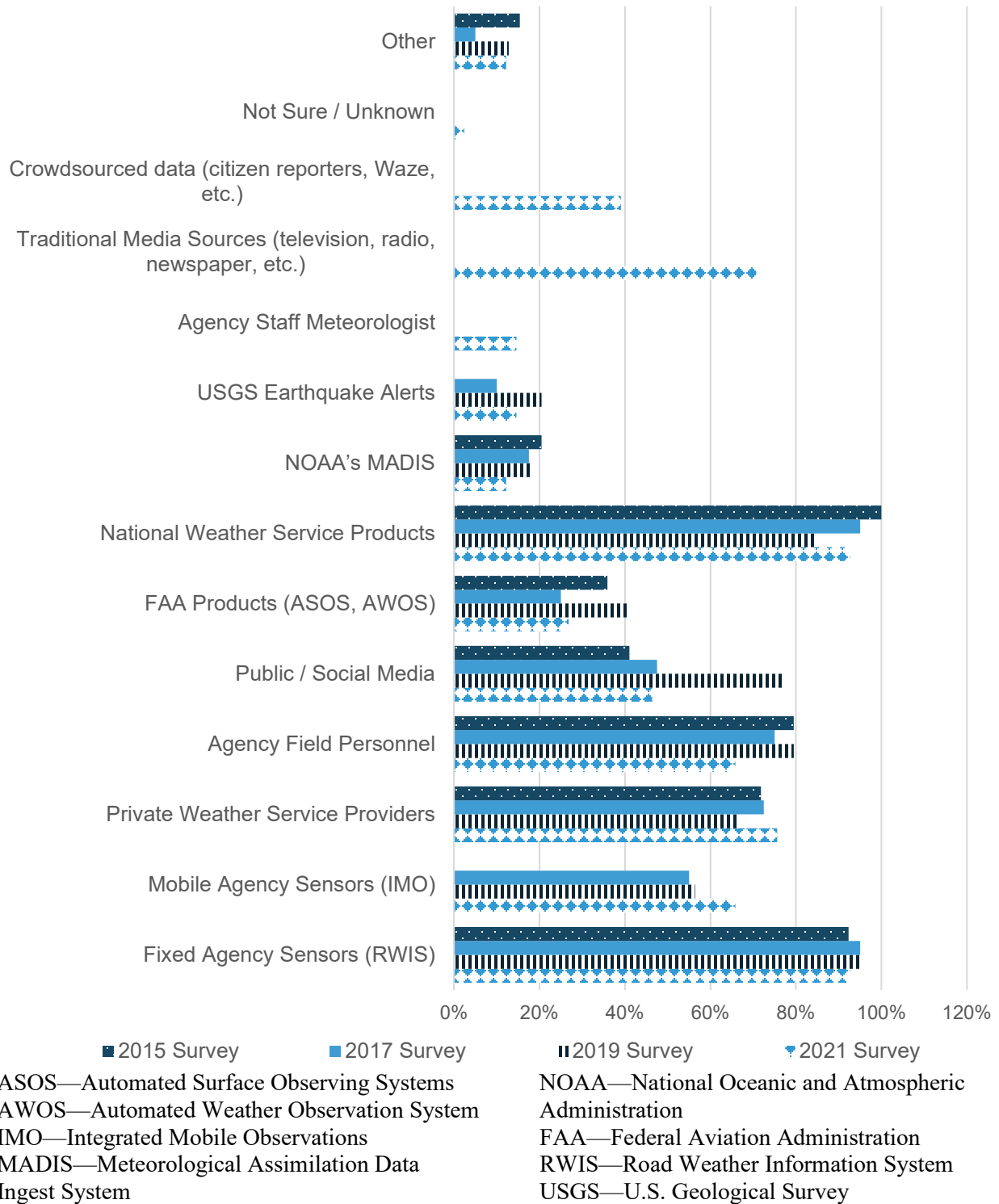
Figure 4. Graph. Percentage of States that subscribe to weather and road weather products and services, 2015–2021

Source: Federal Highway Administration

ASOS—Automated Surface Observing Systems
AWOS—Automated Weather Observation System
IMO—Integrated Mobile Observations
MADIS—Meteorological Assimilation Data Ingest System

NOAA—National Oceanic and Atmospheric Administration
FAA—Federal Aviation Administration
RWIS—Road Weather Information System
USGS—U.S. Geological Survey

The 2021 State DOT survey added several categories of products and services from previous updates, summarized as follows:

- **Crowdsourced data.** The survey revealed 39 percent of respondents use these types of services.

- **Meteorologists on staff.** A small number of agencies (6) with staff meteorologists.

- **Traditional media.** Survey responders reported high usage (71 percent) of traditional media as a data source.

Table 18 summarizes what has been learned by assessing this performance measure, including observations and likely needs for RWMP actions.

Table 18. Assessment of performance measure 8—subscribing to products and services

Overall Rating—Strong Performance			
Submeasure	**Observations**	**Rating**	**Likely Needs for Program**
Subscription and Use of "Traditional" Weather and Road Weather Products and Services	Agency use of most traditional products remains relatively stable. Most agencies continue subscribing to National Weather Service (NWS) products, using fixed agency sensors, and leveraging agency field personnel and private weather service providers.	👍	The Road Weather Management Program (RWMP) may consider identifying and individually reaching out to the relatively few State departments of transportation (DOTs) that do not use these "traditional" products and services to understand their current practices and potentially encourage a workshop to promote use of these offerings.
Subscription and Use of Newer, "Innovative" Weather and Road Weather Products and Services	Agency use of newer and most innovative products remains relatively stable, however there is potential for more agencies to leverage these available products and services, such as mobile agency sensors, crowdsourcing, and social media.	👍	The RWMP should continue developing case studies and conducting outreach activities, such as webinars, workshops, peer exchanges, and stakeholder meeting sessions to promote the benefits of using these innovative products and strategies.

State Collection of Mobile Observations from Vehicle Fleets

State DOTs are increasingly collecting real-time field data from maintenance vehicles. This continues a trend from the 2017 and 2019 updates. Although only 27 survey respondents reported the use of mobile agency sensors when asked about subscriptions to weather and road weather products and services, an additional seven respondents (for a total of 34) indicated that their agency collects real-time data from agency-operated fleet vehicles. The discrepancy may reflect confusion or misunderstanding about the question.

Over four-fifths of respondents (83 percent) of the State DOT survey indicated that their agency collected some form of real-time data from some percentage of their maintenance fleet. Figure 5

shows the distribution for the types of data collected and the percentage of the vehicle fleet by the number of agencies implementing each combination.
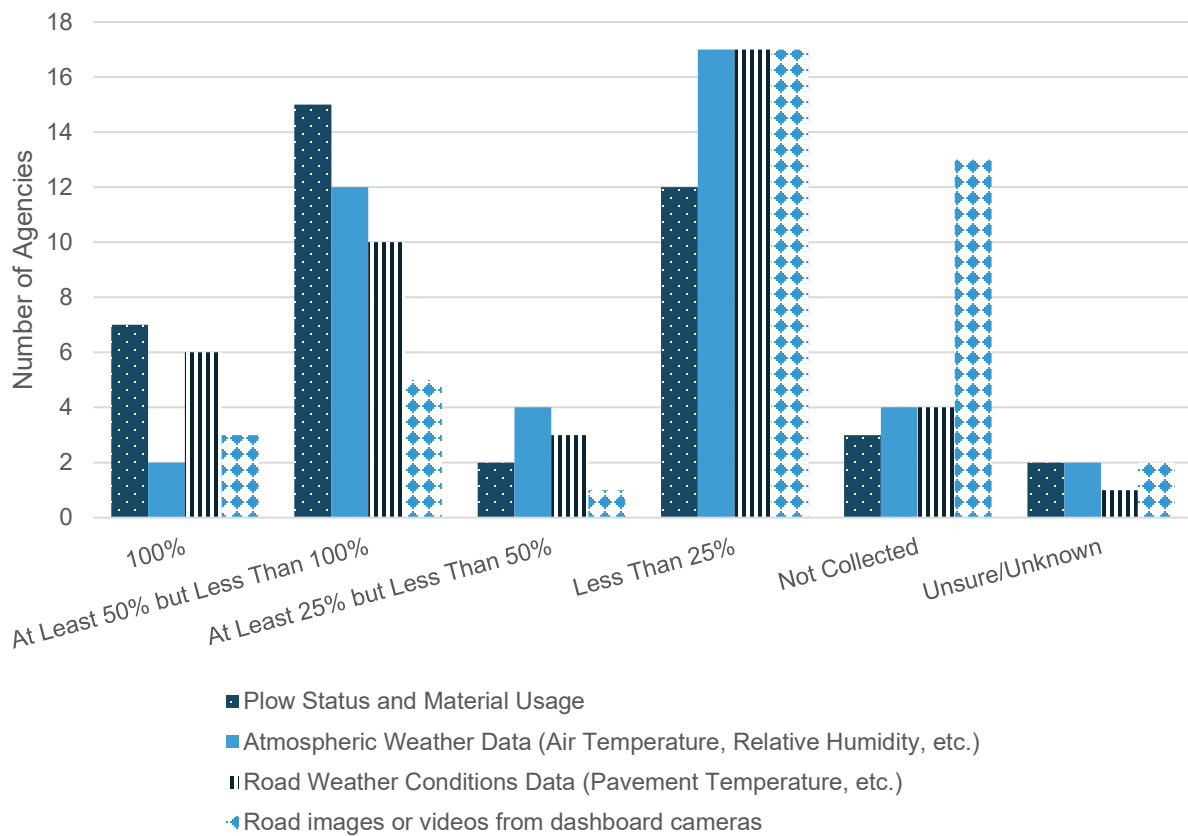
Figure 5. Graph. Responses to the question, "Which of the following data are collected from the maintenance vehicles, and from what percentage of the applicable fleets?"
Source: Federal Highway Administration

The responses to this survey question can be summarized as follows:

- **Plow status and material usage** data have the broadest implementation (22 agencies with 50 percent or more of the fleet equipped).

- **Road weather conditions** data is the next-highest level of implementation (16 agencies with 50 percent or more of the fleet equipped).

- **Atmospheric weather data** reporting from vehicles is slightly less common than road weather data reporting (14 agencies with 50 percent or more of the fleet equipped).

- **Road images or videos** was the lowest reported data collected from vehicles (8 agencies with 50 percent or more of the fleet equipped).

Table 19 summarizes what has been learned by assessing this performance measure, including observations and likely needs for RWMP actions.

Table 19. Assessment of performance measure 9—mobile observations

	Overall Rating—Strong Performance		
Submeasure	**Observations**	**Rating**	**Likely Needs for Program**
Percentage of Agencies	The percentage of agencies that collect real-time fleet vehicle data continues to increase.	👍	The Road Weather Management Program (RWMP) may conduct outreach activities to agencies that are not collecting and using mobile observations in order to understand whether there is a need for further outreach to promote use, depending on the potential benefits of mobile observations to those agencies.
Percentage of Fleet Collecting Various Types of Data	The percentage of agency fleets collecting various types of mobile observations generally continues to increase from previous years, but there remains room for growth for all types of data as relatively few agencies collect data for all fleet vehicles.	👍	The RWMP should continue developing case studies and conducting outreach activities, such as webinars, workshops, peer exchanges, and stakeholder meeting sessions to promote the benefits of expanding the use of mobile observation data, including new and innovative ways to leverage the data. Road images and video is the least collected (and most recently added emerging technology. The RWMP may consider a best practices webinar to allow those agencies that have deployed this to share their experiences with others.

State Use of Environmental Sensor Stations

Respondents from the State DOT survey reported a total of 2,809 permanent ESS, continuing an upward trend—increasing from 2,464 in 2017 to 2,610 in 2019. An additional 33 transportable RWIS (i.e., ESS that may be moved and set up in locations where temporary weather or road condition monitoring is needed) and 9,105 mobile sensors (e.g., sensors installed on snowplows to collect data as the vehicle moves) were also reported by respondents. As in past years, survey respondents reported how the ESS data is being used, which is summarized as:

- **Support traffic management and maintenance decision-making**. A significant majority of respondents (85 percent) indicated ESS data are used to support traffic management and maintenance decision-making, a slightly lower value than 2019 when it was over 90 percent.

- **Inputs for segment level forecasts.** The number of respondents using ESS data as input for segment-level forecasts (53 percent) increased, reversing a decreasing trend seen in the 2019 and 2017 updates.

- **Provide current conditions to traveler information systems.** More respondents indicate using ESS to provide current conditions to traveler information systems than in previous updates (75 percent).

Figure 6 contains additional information.
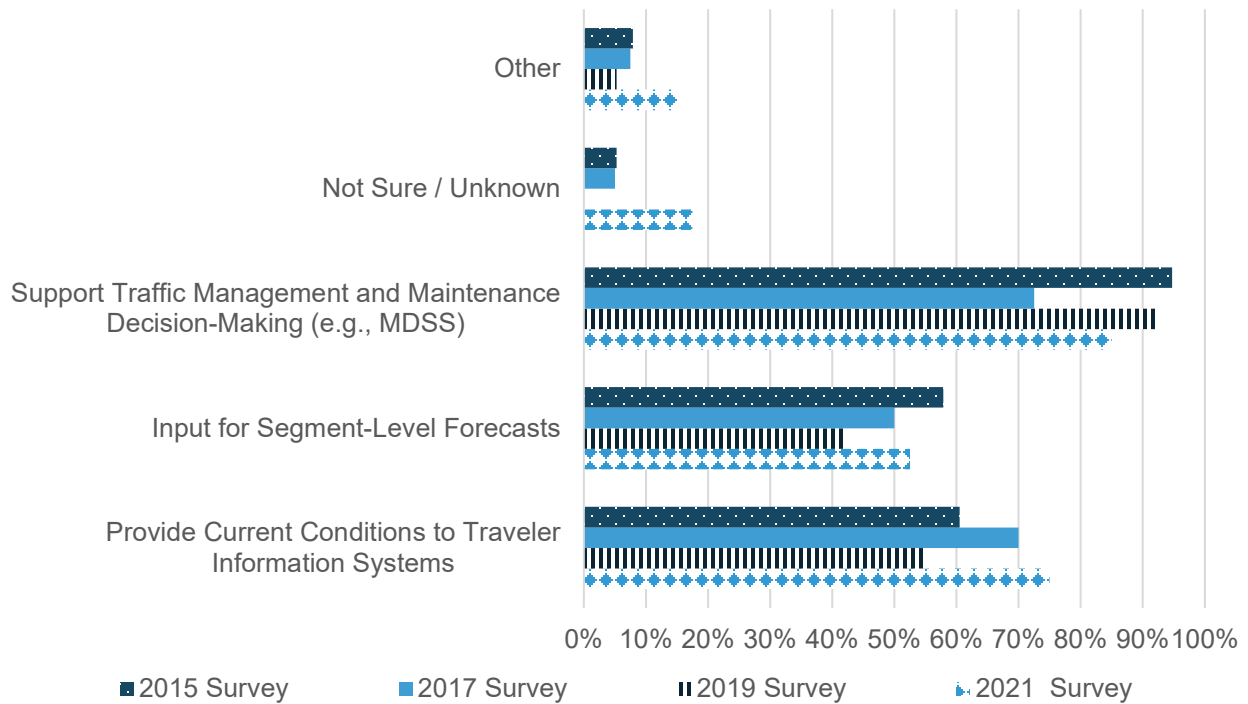
Figure 6. Graph. Use of environmental sensor stations by States, 2015–2021
Source: Federal Highway Administration

Table 20 summarizes what has been learned by assessing this performance measure, including observations and likely needs for RWMP actions.

Table 20. Assessment of performance measure 10—use of environmental sensor stations

Overall Rating: Strong Performance			
Submeasure	**Observations**	**Rating**	**Likely Needs for Program**
Number of Agency Environmental Sensor Stations (ESS)	The number of ESS deployed continues to increase, suggesting that agencies are aware of the value and continue to support the use of ESS.	👍	The Road Weather Management Program (RWMP) may consider individually reaching out to agencies that have few or no ESS in order to provide support, as needed (e.g., demonstrating benefits, facilitating a peer exchange) or to understand why ESS are not deployed (e.g., is there not a need for ESS? Are needs met through other devices?)

Table 20. Assessment of performance measure 10—use of environmental sensor stations (continuation)

Overall Rating: Strong Performance			
Submeasure	**Observations**	**Rating**	**Likely Needs for Program**
Agency Usage of ESS	Agency use of ESS remains relatively stable for various purposes. There may be potential for more agencies to use ESS in ways other than their current practices. Segment-level forecasts may become more critical as automated vehicle use increases and operational design domains are established for weather and driving conditions. The use of ESS for segment-level forecasts may become more critical.	👍	The RWMP may wish to examine how individual agencies are using ESS to determine whether case studies or outreach activities like webinars or sessions at the annual road weather stakeholder meeting are needed to encourage use of ESS. Consider cross-cutting events with automated driving system (ADS) integration research at Federal Highway Administration (FHWA) to assess the need for and role of segment-level forecasts to support the ADS digital infrastructure.

State Use of Mobile Data-based Applications

Figure 7 shows the number of agencies that have developed or are considering mobile applications that use real-time data from vehicle fleets and/or vehicle-to-infrastructure (V2I) technology. Results from the 2021 DOT Survey indicate that 13 agencies (32 percent) have developed an application that uses real-time data from vehicle fleets and/or V2I connectivity, and an additional 23 agencies (54 percent) are considering developing one. These values remain similar to those in the 2019 update, when 16 agencies (44 percent) had developed an application and an additional 17 (47 percent) were considering developing an application.
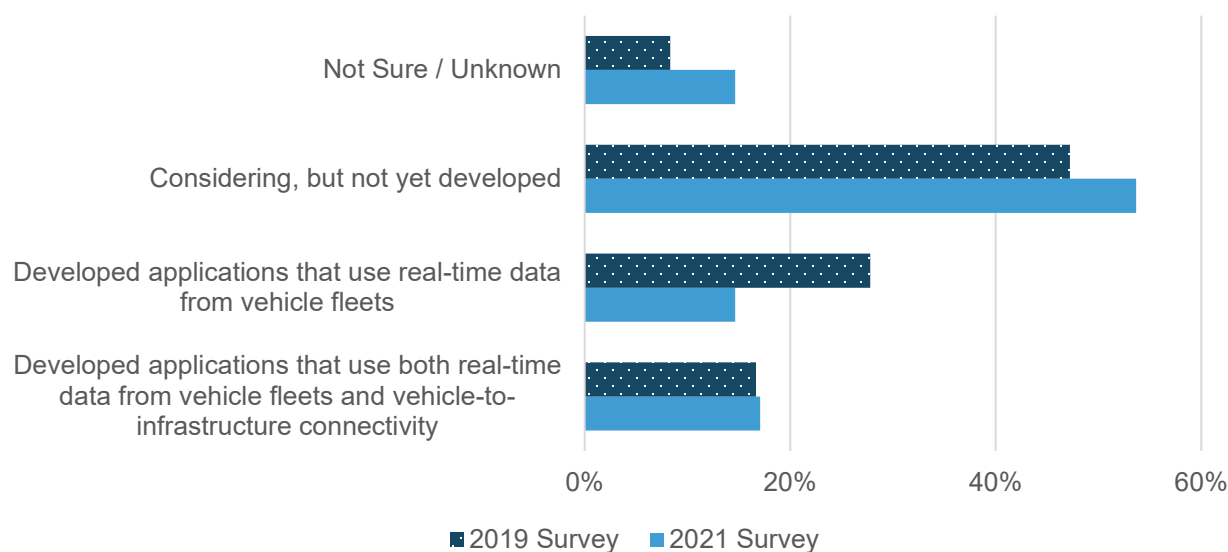
Figure 7. Graph. Survey responses on the use of vehicle-to-infrastructure or infrastructure-to-vehicle connectivity, 2019–2021
Source: Federal Highway Administration

The individual responses to the 2021 surveys were analyzed more closely to understand why positive responses are steady or decreasing. This analysis revealed additional insights:

- In the 2019 survey, four States that responded "considering but not yet developed" or "not sure" responded in the 2021 survey that they have developed applications.

- Additionally, two States that had applications with both fleet vehicle data and connectivity in 2019 and five States with applications using fleet vehicle data, responded "considering but not yet developed" or "not sure" to this question in 2021.

It is possible that an agency that previously developed applications did so only as a short-term research effort and chose to not continue support for the activity, or that they changed the nature of the applications. The number of States with different responses in application availability or capabilities suggests, however, possible gaps in respondents' understanding of their agency's activities in application use and development. Thus, the decrease in agencies with developed applications may reflect a change in the agency representatives who responded to the survey and their understanding of the applications.

The following table summarizes what has been learned by assessing this performance measure, including observations and likely needs for RWMP actions.

Table 21. Assessment of performance measure 11—Use of mobile data based applications

Overall Rating—Moderate Performance			
Submeasure	**Observations**	**Rating**	**Likely Needs for Program**
Agencies Developing Applications	Agency mobile data-based application development has decreased somewhat, although interest in applications has increased (as well as respondents who were unsure).	👆	The RWMP should consider developing case studies to highlight benefits and successful mobile data-based applications that are being used, facilitate the sharing of developed applications between agencies, and/or conduct outreach activities like workshops or peer exchanges to encourage greater agency use of these applications.

State Dissemination of Advisory Weather and Road Weather Information to Travelers

State DOTs disseminate advisory and road weather information to travelers through many mechanisms.

- **Dynamic message signs (DMS) for atmospheric weather conditions.** The percentage of agencies deploying DMS to convey atmospheric weather information has remained steady at 71 percent (72 percent in the prior period). In the current period, 51 percent of agencies report full Statewide deployment.

- **DMS for road condition information.** The percentage of agencies deploying road condition information Statewide on DMS is similar to what was reported in the 2019 survey—currently 56 percent, a slight decrease from 59 percent in 2019. When partial deployment is included, the percentage rises to 90 percent in the current period.

- **Highway advisory radio for road conditions.** Fewer agencies use highway advisory radio to disseminate road condition information Statewide than during the previous reporting period—currently 15 percent, down from 49 percent. When including partial deployment, the percentage rises to 39 percent for the current period.

- **Social media and mobile applications.** A larger percentage of agencies use agency-hosted social media and mobile applications to disseminate information to travelers on road weather conditions—68 percent in the 2021 survey, up from 23 percent in 2019. When including limited or partial deployment, this percentage rises to 88 percent for the current period.

- **Websites and 511 phone systems.** The percentage of agencies disseminating road conditions through agency-hosted websites or 511 phone systems remains relatively constant—83 percent of agencies disseminate road weather information Statewide through these mechanisms.

Figure 8 summarizes survey responses.
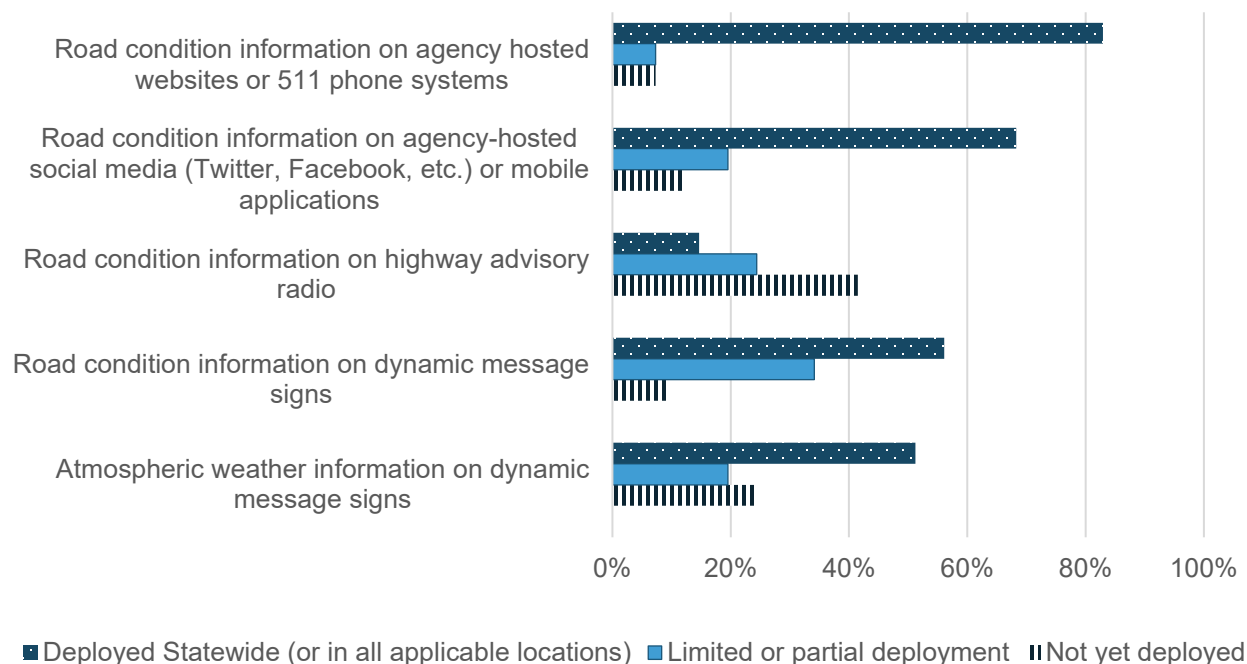
Figure 8. Graph. Survey responses on the dissemination of advisory weather and road weather information to travelers
Source: Federal Highway Administration

The 2021 State DOT survey responses also indicate a significant number of agencies have deployed safety warning systems (e.g., variable speed limit systems, dynamic roadside signs, or static signs with beacons) for a variety of road weather events. This includes safety warning systems for icy roads (21 agencies, 52 percent), flooding (17 agencies, 42 percent), fog (13 agencies, 32 percent), wind (18 agencies, 44 percent), and dust (7 agencies, 17 percent). These numbers mostly reflect a slight increase from responses received in the 2019 State DOT survey:

icy roads (18 agencies, 47 percent), flooding (13 agencies, 34 percent), fog (14 agencies, 37 percent), wind (11 agencies, 29 percent), and dust (4 agencies, 11 percent).

Table 22 summarizes what has been learned by assessing this performance measure, including conclusions and likely needs for the RWMP.

Table 22. Assessment of performance measure 12—dissemination of weather information

Overall Rating—Strong Performance			
Submeasure	**Observations**	**Rating**	**Likely Needs for Program**
Traveler Information Dissemination	Generally, agencies continue to use a variety of mechanisms to disseminate road weather traveler information at consistent levels.	👍	The Road Weather Management Program (RWMP) may wish to conduct general or targeted outreach to encourage agencies to disseminate more types of road weather information Statewide through all appropriate mechanisms (e.g., agency-hosted website and dynamic message signs (DMS)).
Safety Warning Systems	The number of agencies deploying safety warning systems for road weather conditions continues to increase.	👍	The RWMP may develop case studies to highlight benefits and successful safety warning systems and conduct workshops or peer exchanges to encourage agency use of these systems.

State Coordination with Local National Weather Service Forecast Offices

Local weather forecast information is a critical input in road weather management and operations decision making. The RWMP supports the 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. Most respondents (93 percent) indicated that their agency worked with their local forecast offices, with 68 percent indicating routine coordination with NWS during winter and 59 percent during non-winter seasons.

Additionally, the 2021 survey asked respondents if the decision to deploy any road weather information strategy was influenced by FHWA's Pathfinder Initiative, which promotes collaboration with the NWS for better, more consistent messaging. Respondents from 25 agencies (61 percent) said this was true, while 16 agencies (39 percent) said no or they were not sure. Figure 9 shows that 78 percent of agencies use Pathfinder principles to coordinate messaging with the NWS Statewide or as a partial deployment for winter, and 68 percent for non-winter weather events.
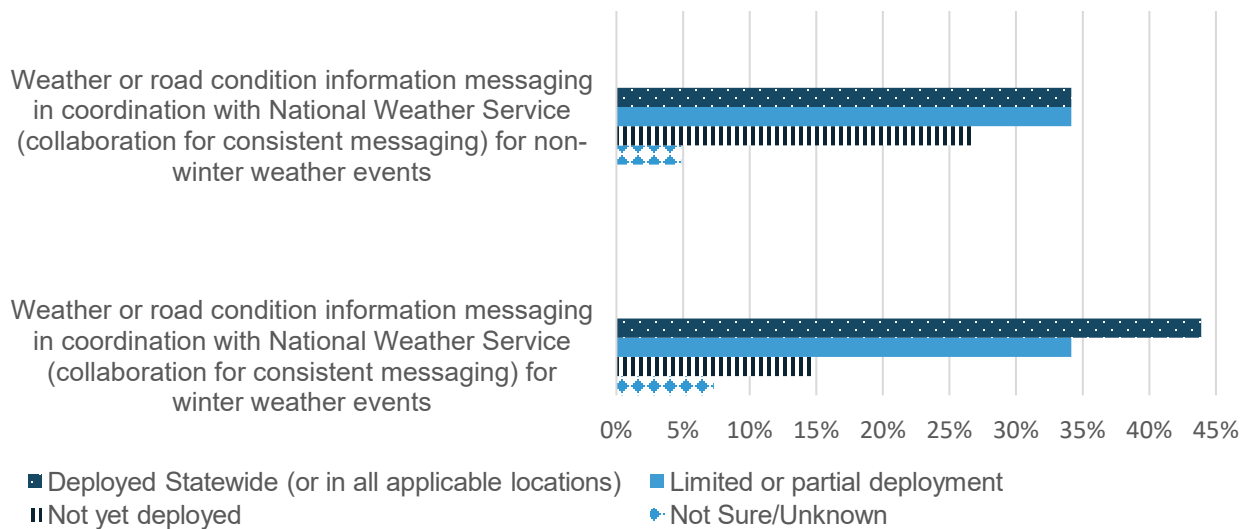
Figure 9. Graph. Survey responses on agency coordination of messaging with the NWS for winter and non-winter weather events

Source: Federal Highway Administration

Table 23 summarizes what has been learned by assessing this performance measure, including conclusions and likely needs for the RWMP.

Table 23. Assessment of performance measure 13—coordination with National Weather Service

Overall Rating—Strong Performance			
Submeasure	**Observations**	**Rating**	**Likely Needs for Program**
Agency Coordination with Local Forecast Office	A significant percentage of agencies continue to coordinate with the National Weather Service (NWS) for both winter and non-winter weather events.	👍	The Road Weather Management Program (RWMP) should continue to encourage agencies to coordinate with the NWS. This may include continued promotion of the Pathfinder initiative as a mechanism to increase agency coordination with NWS, particularly to States that have not yet officially implemented it in order to formalize the agency processes and interactions with the NWS.
Pathfinder Initiative	A significant percentage of agencies coordinate with the NWS for messaging for both winter and non-winter weather events, and more than half attribute this to Federal Highway Administration (FHWA) efforts.	👍	The RWMP should continue to promote the Pathfinder initiative to States that have not yet implemented it, and also promote expansion of Pathfinder practices to additional types of events and Statewide.

State Adoption of Decision Support Technologies and Methods

The percentage of State DOTs using decision-support systems (DSS) reflects similar values to the 2019 update (which asked specifically about maintenance DSS), both for Statewide usage (29

percent) and not Statewide usage (17 percent). Broadening this question for the 2021 update to include all DSS rather than just MDSS as in previous years could explain changes, so additional conclusions are not drawn from this. Figure 10 presents this information graphically.
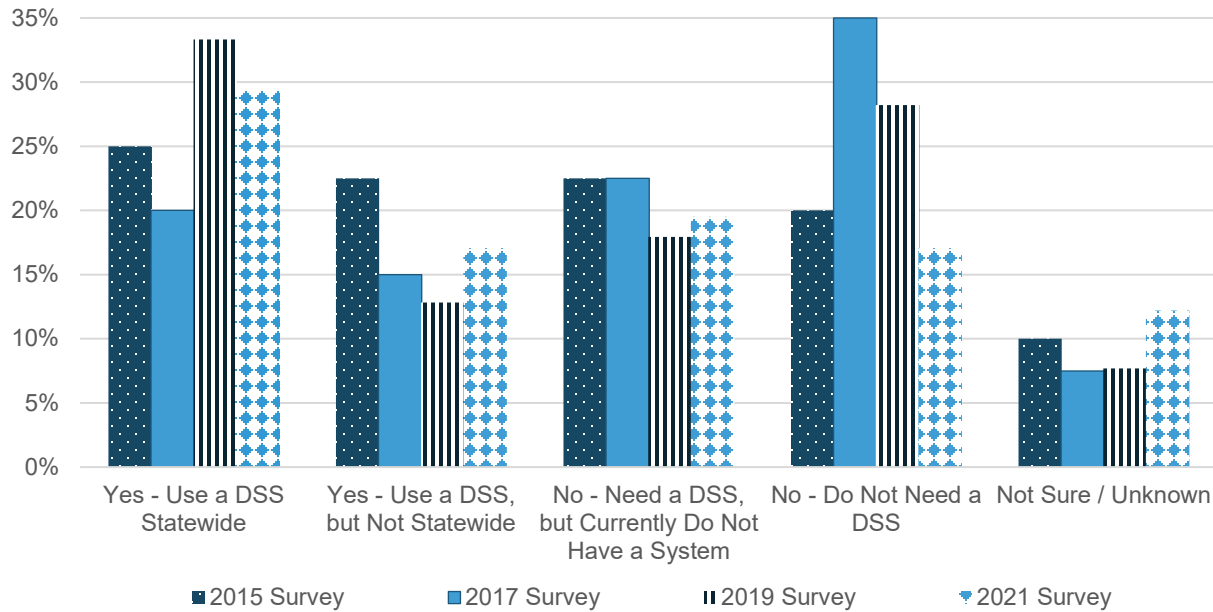
Figure 10. Graph. Percentage of State DOTs indicating use and non-use of DSS, 2015–2021
Source: Federal Highway Administration

Additionally, the percentage of agencies using decision support tools to provide current traveler information has decreased steadily to 42 percent—down from over 75 percent in the 2015 update. Other surveyed uses of decision support tools (coordination with other jurisdictions and agencies, supporting non-winter maintenance activities, traffic control and management, setting seasonal load restrictions) remain similar to those in the 2019 update.

Table 24 summarizes what has been learned by assessing this performance measure, including conclusions and likely needs for the RWMP.

Table 24. Assessment of performance measure 14—decision support systems

Overall Rating—Moderate Performance			
Submeasure	**Observations**	**Rating**	**Likely Needs for Program**
Agency Use of Decision Support Systems	Agency use of decision support systems remains similar to the 2019 update.	👉	The Road Weather Management Program (RWMP) may develop case studies to highlight benefits and successful decision support systems that are being used and conduct outreach activities like workshops or peer exchanges to encourage greater agency use of these systems.

5. Knowledge and Technology Transfer

OVERVIEW

The mission of the Road Weather Management Program (RWMP), to lead and support the road weather community in developing and deploying innovative technologies, solutions, and strategies, is achieved through successful knowledge and technology transfer. For this assessment, the program's success at conducting knowledge and technology transfer is assessed by the level of participation in Federal Highway Administration (FHWA)-sponsored external training and capability assessments, along with how well RWMP activities align with advances and trends in road weather management (RWM) in the next 5 to 10 years

The assessment found continued interest among State departments of transportation (DOTs) in assessing their road weather programs and that that RWMP activities largely align with advances and trends. Nevertheless, the RWMP should work with State agencies and research institutions to enable more discussion and understanding of newer advances and trends that have less real-world application. For this reporting period, external training did not take place because the course content required significant updating. A likely need is for the RWMP to continue conducting outreach to promote the RWM Capability Maturity Framework (CMF) as well as the updated training (when it becomes available). The RWMP should also maintain its focus on data use, collaboration, and severe weather. The RWMP should also work with organizations to identify deployments related to automated decision making and vehicle automation to enable more discussion and a better understanding of those two focus areas.

Table 25. Knowledge and technology transfer overview

Performance Measure	Ranking	Observations	Likely Needs for Program
Number of agencies and attendees who have taken any of the sponsored Road Weather Management Program (RWMP) training courses and workshops	👎	No external, training occurred during this reporting period. Training course currently being updated and was unavailable.	Conduct broad outreach to raise awareness of web-based training once updates complete.
Number of agencies that conduct periodic assessments of road weather management (RWM) capabilities or performance	👍	Continued interest in conducting assessments of State department of transportation (DOT) road weather programs.	Continue to promote updated Capability Maturity Framework (CMF).

Table 25. Knowledge and technology transfer overview (continuation)

Performance Measure	Ranking	Observations	Likely Needs for Program
Number of RWM meetings and webinars that include topics specific to each of the program focus areas and trends	👍	Mixed findings based on topic area—expanded data collection and use, collaboration, and severe weather events broadly covered across the RWMP activities. Automated decision making often discussed but not always a prioritized topic. Lack of focus for vehicle automation in general.	For the topics covered broadly, continue to plan for and conduct events as has been done in the past. For others, work with agencies and research institutions to identify deployment cases to enable more discussion and understanding of topic.

FINDINGS

Agency Participation in FHWA RWMP-Sponsored Training

Over the course of the 2019 -2020 reporting period, the RWMP was largely focused on webinars, events, and program-specific workshops (which have been evaluated under performance measures 2, 16, and 17). The results of each of these measures was strong agency and industry participation in such events and continued interest. Alternatively, this measure (number 15) evaluated whether additional trainings were held beyond those programmatic trainings, such as those previously conducted via the Consortium for Innovative Transportation Education (CITE). During this reporting period no such trainings occurred.

There are a few reasons for the lack of training. First, updates to the CITE course are currently underway via a contract vehicle through the National Highway Institute (NHI). These updates are critically needed as the course content is nearly 20 years old, and largely out of date with the many advancements that have occurred in RWM. Additionally, it's likely that had the training been offered, given the age of the training, most States were expected to have participated in the training in prior years and likely to have no additional need to retake it.

Table 26. Assessment of performance measure 15—Road Weather Management Program-sponsored training

Overall Rating—Needs Improvement			
Submeasure	Observations	Rating	Likely Needs for Program
Training Records	During this reporting period no external, Road Weather Management Program (RWMP)-sponsored trainings occurred as the training was outdated and pulled from public website access.	👎	Once the revised National Highway Institute (NHI) course is completed, the RWMP should conduct a broad outreach effort (GovDelivery, industry events, etc.) to raise awareness of the updated web-based training and how stakeholders can sign up.

Agency Participation in FHWA RWMP-Sponsored Capability Assessments

For several years the RWMP has been developing, enhancing, and conducting RWM CMF assessments across the country to evaluate the institutional capacity of an agency (or region) to respond to adverse weather conditions. Once assessed, the findings are used to develop a list of prioritized actions that can be used by the agency/region to increase capabilities in road weather management. Since the 2019 update, an additional three agencies have conducted the workshop, bringing the total number of State DOTs involved up to 19. During this period, the pandemic led to significant delays and resulting changes in priorities by several States. Nonetheless, interest in the workshops persisted and the team was able to pivot and conduct meaningful virtual engagements.

Several anecdotal benefits were noted by participating agencies:

- **Getting everyone in "the Same Room."** Nearly every State noted the importance of getting all the RWM players into one room to discuss their programs. This was especially valuable to the larger States that, due to their size, organizational structure, and assigned roles and responsibilities, do not often (if ever) get their personnel into the same room together. These workshops enabled "boots on the ground" staff along with HQ staff, managers, and decision-makers to meet and discuss their program.

- **Cross-sectional representation**. Due to the nature of the assessment, a cross-section of agency personnel (weather, first responders, traffic operations, public works, and field staff) is involved in the process. This enables these different staff members to see the importance/value of working together toward improved RWM in ways they may never have considered.

- **Sharing of ideas**. The assessment laid the groundwork for many of the agencies to develop a framework for a periodic sharing of ideas.

- **Regional problem solving.** It was noted that none of the issues identified were surprising. However, the workshops provided forums for regions to reprioritize these issues and develop criteria for improvements at a regional level with all the stakeholders in the room.

- **Formal Framework**. While many RWM activities occur independently and/or on an ad hoc basis, the CMF assessment provided agencies/regions the opportunity to formalize these activities in a larger action plan/framework. It helped bring the discussion to a higher, more strategic level which was noted as a very beneficial contribution.

- **Prioritizing RMW activities**. The issue of having to "do more with less" often came up during the discussions. It was noted that the CMF process helps agencies stay on track and push for the deployment of specific actions in an atmosphere of competing budget and staffing priorities. It "puts a fire" under State DOTs to get more done.

- **Identifying What you didn't know.** It was noted that the CMF assessment helped agencies and regions realize things they "hadn't thought of" regarding their RWM programs.

Significant changes were also made to the RWM CMF during this time period. An internal assessment of lessons learned was conducted, finding substantial changes had occurred in road weather management over the last 5 years of implementation. Agency needs evolved, as had agency and weather event focus. As a result, there was a clear need for flexibility. Based on this, the framework was modified to include non-winter weather, event-specific assessments, and the ability to have variances in maturity across weather type. The CMF was updated to include modular weather-event based modifications (questions expanded for event related modifications) as well as updates based on RWM practice enhancements (language revised to account for RWM developments). The last workshop conducted during this review period was a pilot for this updated CMF. It was viewed as a success by the State DOT.

Table 27 summarizes what has been learned by assessing this performance measure, including conclusions and likely needs for the RWMP.

Table 27. Assessment of performance measure 16—Road Weather Management Program capability assessments

Overall Rating—Strong Performance			
Submeasure	**Observations**	**Rating**	**Likely Needs for Program**
Capability Maturity Framework (CMF) Assessments across State Agencies	Agencies continue to be interested in conducting assessments of their programs via the Road Weather Management (RWM) CMF.	👍	Updates to the RWM CMF are new and should continue to be promoted through outreach activities. The new modular and flexible nature of the CMF will probably be useful both to agencies that have not yet conducted an assessment and to those that have previously conducted assessments and are ready to see where their agency stands after the CMF changes.

Events Inclusive of Program Focus Areas and Trends

For the 2021 update, a new measure was added to assess how well the RWMP events (i.e., meetings and webinars) include RWMP focus areas and trends. The intent of this measure is to evaluate whether activities are in alignment with advances and trends in road weather management likely in the next 5 to 10 years. These focus areas include:

- **Expanded data collection and use.** Agency use of new or expanded data sources to enhance road weather management strategies and make more informed decisions. This may involve the deployment of new technologies for increased data collection (e.g., plow sensors), procurement of third-party data (e.g., probe data), or use of crowdsourced data from social media or citizen reporting.

- **Collaboration**. Agency use of strategies like Pathfinder that increase DOT collaboration with other entities, such as NWS, neighboring State DOTs, local agencies, and other transportation system management and operations functions in the DOT.

- **Vehicle automation**. Agency use of levels 1–5 automation for agency fleet vehicles (e.g., plows) and road weather management in support of personal vehicle and commercial motor

vehicle automation (e.g., road weather data and applications). This is generally broad now due to the evolving nature of vehicle automation and may be further broken up in future updates.

- **Automated decision making**. Agency use of analytics involved with data processing and data fusion capabilities at a DOT to automate decision-making processes and functions (e.g., road treatment location, type, and timing; variable speed limits; road closures).

- **Focus on severe weather**. Focuses on an expanding emphasis of FHWA and DOT programs beyond winter weather. Events to flooding, wildfires and tropical weather, as well as their impacts (e.g., burn scars) are included.

Of the focus areas, Collaboration and Focus on Severe Weather were discussion topics in all 10 events assessed. The next most frequently discussed topic was Expanded Data Collection and Use, discussed during 70 percent of events. Automated Decision Making was covered by half of the events, while Vehicle Automation was only covered by 30 percent of the events. These findings are consistent with the hot topics and interest noted by stakeholders during the last two years through discussions with the RWMP as well as through formal channels such as surveys conducted during the Annual RWM Stakeholder Meeting. Automated Decision Making as well as Vehicle Automation, while innovative, have less real-world applications and deployment, and were not discussed.

The following table summarizes what has been learned by assessing this performance measure, including conclusions and likely needs for the RWMP.

Table 28. Assessment of performance measure 17—program focus areas

Overall Rating—Strong Performance			
Submeasure	**Observations**	**Rating**	**Likely Needs for Program**
Expanded Data Collection and Use	The topic of expanded data collection and use is covered across most events.	👍	Continue to plan for and conduct events as has been done in the past.
Collaboration	There is clear and extensive coverage of collaboration among Road Weather Management Program (RWMP) activities.	👍	Continue to plan for and conduct events as has been done in the past.
Vehicle Automation	There is a lack of focus on vehicle automation among RWM events. Given the newness of the topic and its lack of broad application, this is to be expected.	👎	Work with State agencies and research institutions to identify pilots and other use cases of innovation with respect to vehicle automation to enable more discussion and understanding of the topic among the RWM stakeholders

Table 28. Assessment of performance measure 17—program focus areas (continuation)

Submeasure	Observations	Rating	Likely Needs for Program
Overall Rating—Strong Performance			
Automated Decision making	Automated decision making is often discussed but does not appear to be a topic of priority among many events.	👊	Work with State agencies and research institutions to identify pilots and other use cases of innovation with respect to automated decision making to enable more discussion and understanding of the topic among the RWM stakeholders
Focus on Severe Weather	There is clear and extensive coverage of severe weather across the RWMP activities.	👍	Continue to plan for and conduct events as has been done in the past.

6.   Innovation, Resilience, and Sustainability

OVERVIEW

One focus of the Road Weather Management Program (RWMP) is promoting innovation, resilience, and sustainability by communicating innovative solutions, standards, approaches, and data needs for road weather management. The 2021 assessment determined the degree to which the RWMP successfully promotes innovation, resilience, and sustainability on the basis of State agency adoption and use of new approaches to road weather management, as well as the planning and preparation States have implemented for resilience and sustainability. While other factors beyond RWMP activities influence State agency initiatives in this area, this assessment assumes that RWMP activities are a contributing factor to the identified performance measures. Performance measures in this category rely largely on State department of transportation (DOT) survey responses, as well as external data reported by national sources. Two performance measures (reduction in fatal or serious crashes, and reduction in salt use) have many contributing factors beyond those that the RWMP can influence; severity of the winter season has the largest impact. For these measures, external data from national sources was incorporated to the extent possible, as for previous assessments. The assessment found positive impacts from promoting innovation. The assessment of resilience and sustainability found mixed messages about agency adoption, with survey responses suggesting that responders may not be aware of their agencies' activities. A likely need is for the promotion of innovation continue as is, and the RWMP communicate with agencies to understand whether resilience and sustainability should remain focus areas.

Table 29. Innovation, resiliency, and sustainability overview

Performance Measure	Assessment	Findings	Likely Needs for Program
Reduction in number and types of fatalities and crashes attributed to adverse weather nationally	✊	There is no data that suggests a significant change in fatal crashes related to inclement weather when considering either the crash rate per billion vehicle miles traveled (VMT) or per licensed drivers.	The Road Weather Management Program (RWMP) should consider continuing all activities to support safety during inclement weather and road weather events. There are anecdotal reports of increased safety and it is encouraging that fatal crashes are not increasing.

Table 29. Innovation, resiliency, and sustainability overview (continuation)

Performance Measure	Assessment	Findings	Likely Needs for Program
Reduction in number of tons of salt or chemical usage in the United States normalized by winter severity index	👍	Salt use remains relatively constant at the national level, suggesting that strategies for reducing salt use are not widespread enough to have an impact on overall use. Salt use varies; for example, mild winters typically cause dips in usage. Some creative, innovative approaches to reducing salt usage reflect positive impacts of the RWMP.	Consider identifying State departments of transportation (DOTs) willing to provide their salt consumption statistics to correlate States' implementation of new snow and ice management approaches with reduction in salt usage. Consider outreach to so that agencies with salt reduction approaches can share the approaches with other State DOTs. Track salt use by agencies adopting these approaches in future performance assessments.
Diversity of traffic control and road treatment strategies used by agencies during weather events	👍	Agency use of diverse traffic control and road treatment strategies during inclement weather is strong.	Continue outreach activities, with minor suggested changes to include: outreach activities to allow agencies using intelligent transportation systems (ITS) to determine vehicle restrictions to demonstrate these to other States; working with traffic engineering groups to explore wider use of traffic management approaches to respond to weather events, determining route selection or chemical application rates, and unmanned aerial systems (i.e., drones).

Table 29. Innovation, resiliency, and sustainability overview (continuation)

Performance Measure	Assessment	Findings	Likely Needs for Program
Number of agencies reporting use of appropriate analysis tools to factor weather impacts and strategies		Agency use of real-time tools for roadway maintenance is very strong. Agencies reported moderate use of real-time traffic control or management, and post-event analysis. There was limited use of tools for the prediction of impacts of road weather management (RWM) strategies.	Consider additional outreach activities related to real-time traffic control and post-event analyses. Consider increasing activities to help agencies understand the existence of tools for predicting impacts of RWM strategies and encourage use, if appropriate.
Number of agencies conducting vulnerability risk assessment or developing or implementing resiliency plans for their RWM infrastructure and processes to respond to climate change and extreme weather		There was little to no change from the 2019 survey in agency responses to participation in climate change adaptation planning and preparation of extreme weather response processes. Agency responses about extreme weather participation indicate that more than half of responders (57 percent) indicated they had participated in extreme weather response planning, but individual agency responses were inconsistent from 2019 to 2021 (e.g., some agencies that reported in 2019 they had participated in climate change activities reported in 2021 they had not), suggesting that knowledge of these activities by the individuals responding each year varies. Participation in vulnerability risk assessments and resilience planning for RWM is low, with less than 20 percent of responders indicating participation.	Consider activities to reintroduce the benefits of extreme weather planning and climate change adaptation planning. Consider new activities to encourage vulnerability and resilience actions to increase participation by agencies.

FINDINGS

Impacts on Fatalities and Crashes Attributed to Adverse Weather Nationally

This measure assessed the reduction in number and types of fatalities and crashes attributed to adverse weather conditions. Although the impact of the RWMP on fatalities and serious crashes is difficult to establish, the biannual performance measures assessment has included consideration of fatalities and serious injuries. Two statistical values were examined for this assessment and are described below and illustrated in the graphs that follow:

- **Fatal crashes per thousand licensed drivers.** Fatal crashes during inclement weather make up a small proportion of the crash rate per thousand licensed drivers. Comparing six years of data (2014–2019) little change is found in the fatal crash rate per thousand licensed drivers, with 2019 reporting 0.015 fatal crashes per thousand licensed drivers. Figure 11 illustrates fatal crash rates per thousand licensed drivers.

- **Fatal crashes per billion VMT.** When compared against billion VMT, fatal crashes remain mostly constant, but a slight decline is observed in 2019 from the previous two years. Again, fatal crashes during inclement weather make up only about 10 percent of total fatal crashes, and VMT during inclement weather is probably a low percentage of VMT, but national figures on this subset of VMT are not available. Figure 12 illustrates fatal crashes by VMT.

Table 30 summarizes what has been learned by assessing this performance measure, including conclusions and likely needs for the RWMP.
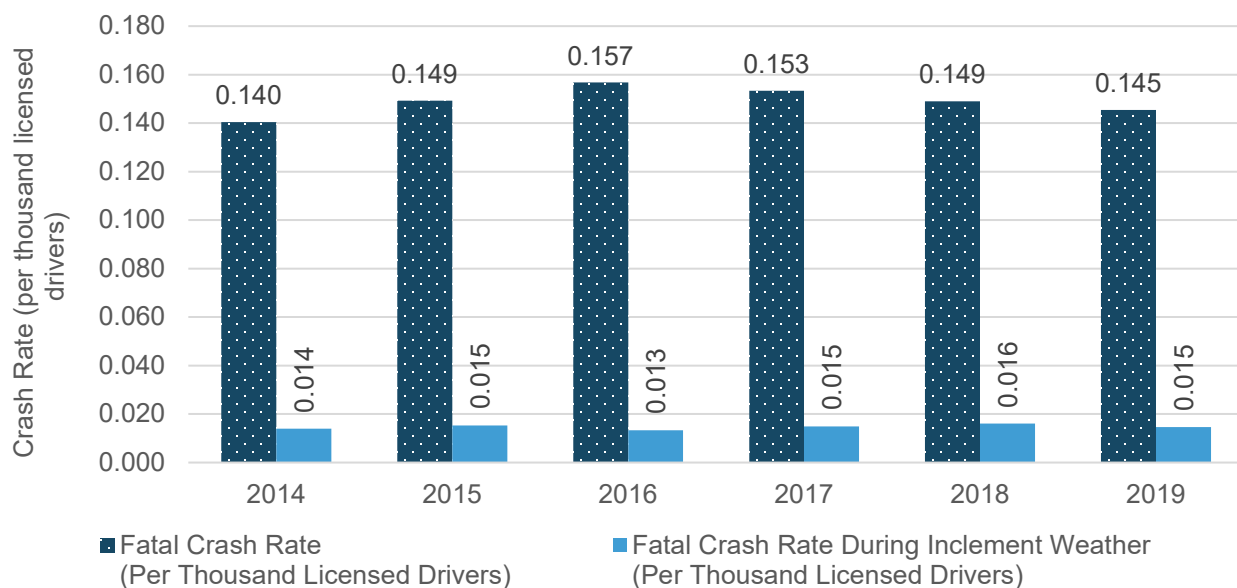
Figure 11. Graph. Fatal crash rates per thousand licensed drivers, 2014–2019
Source: National Highway Transportation Safety Administration Fatality Analysis Reporting System
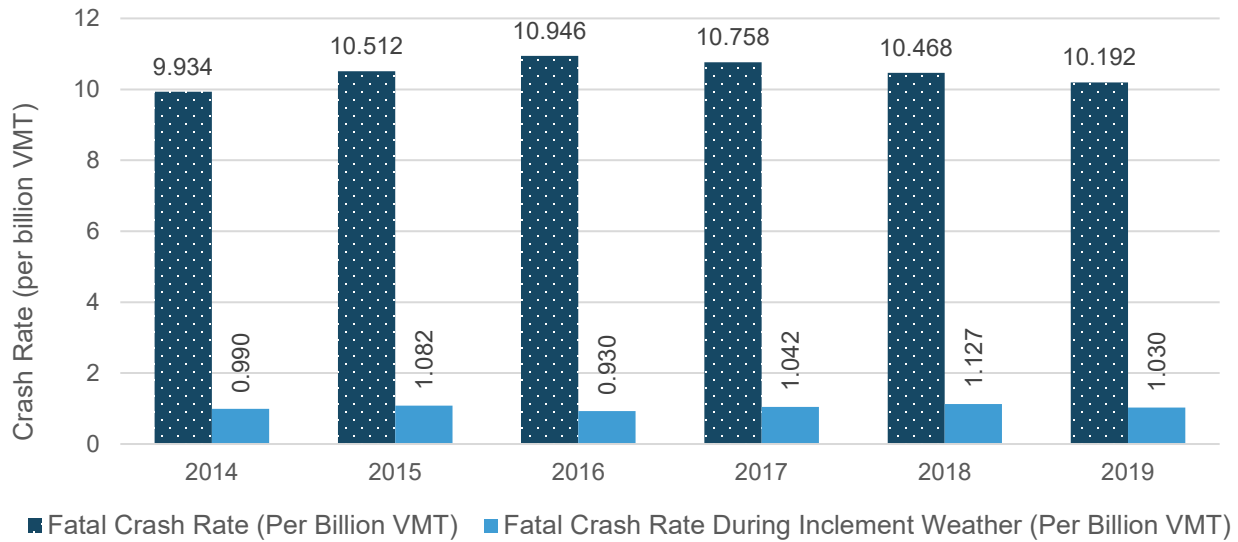
Figure 12. Graph. Fatal crash rates per billion vehicle miles traveled, 2014–2019
Source: National Highway Transportation Safety Administration Fatality Analysis Reporting System

Table 30. Assessment of performance measure 18—impacts on fatalities and crashes

Overall Rating—Moderate Performance			
Submeasure	**Observations**	**Rating**	**Likely Needs for Program**
Impacts on Fatal Crashes	There is no data that suggests a significant change in the fatal crashes related to inclement weather when considering either the crash rate per billion vehicle miles travelled (VMT) or per licensed drivers. 2019 experienced reductions in fatalities both considering crashes per thousand licensed drivers and crashes per billion VMT. However, earlier years also showed few fatal crashes, therefore it is unknown if this represents a downward trend or the cycle seen through past years.	✊	The Road Weather Management Program (RWMP) should consider continuing all activities to support safety during inclement weather and road weather events. There are anecdotal reports of increased safety and it is encouraging that fatal crashes are not increasing.

Reduction in Number of Tons of Salt or Chemical Usage in the U.S.

Total tons of salt used for treatment of roads has remained relatively consistent since 2010, according to statistics reported by the United States Geological Society (USGS) Minerals Yearbook. Although amounts fluctuate each year, much of the fluctuation is attributable to the extent to which conditions are conducive to ice on the roadway. There was a 12 percent reduction in salt consumed for treatment of roads in 2020, but as the USGS Minerals Yearbook reports, the 2019-20 winter season was milder than the preceding several years. State DOT demand for and purchase of salt in 2020 was lower as State DOTs reported having stockpiles from the previous season. Figure 13 illustrates nationwide salt use from 2015 through 2020.
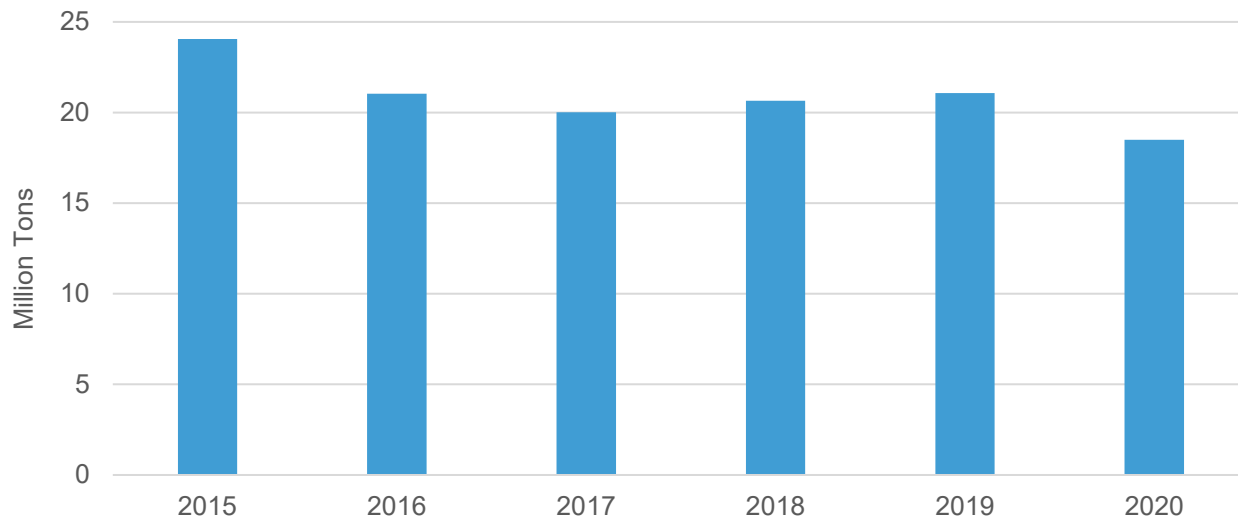
Figure 13. Graph. Nationwide salt usage by year (in millions of tons), 2015–2020
Source: United States Geological Society Minerals Yearbook

Although dips in salt usage related to mild conditions is not the intent of this performance measure, anecdotal descriptions of actions State DOTs are taking to transition away from the use of salt (or to use salt more efficiently) reflect impacts that the RWMP is likely having on the use of salt. The following anecdotal examples reflect success stories:

- In December 2020, the Salt Reduction Act was enacted in New York State to reduce salt usage in the Adirondack region. This legislation has created a 3-year program to test data-driven salt reduction tactics.[14]

- In 2019 Minnesota DOT compiled a list of best practices for reducing the use of salt on roadways, while maintaining a high level of performance. These practices were broken into five sections: training and information sharing, calibrating equipment, decision making, material handling and storage, and estimating effectiveness. [15]

- Traverse City, Michigan used a product called Beet Heet to reduce their dependance on salt over the winter. Beet Heet is an organic-based, corrosion-inhibited, liquid deicer. The product is more efficient at melting ice and is effective to much lower temperatures than the salt the city currently uses. Additionally, it was stated, Beet Heet is much less corrosive than salt and is rapidly biodegradable. Furthermore, the efficacy of its use translates into a substantial cost savings to the city when compared to the status quo.[16]

Table 31 summarizes what has been learned by assessing this performance measure, including conclusions and likely needs for the RWMP.

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[14] "Road Salt Reduction Act Signed into Law." December 2, 2020. AdkAction. https://www.adkaction.org/roadsalt/road-salt-reduction-act-signed-into-law/
[15] *Winter Maintenance Best Practices*. February 2019. Minnesota DOT Salt Sustainability Project. http://www.dot.state.mn.us/maintenance/files/salt_sustainability/BestPractices_FINAL_2-25-19.pdf
[16] Milligan, Beth. "City to Use Eco-Friendly Alternative to Road Salt." December 24, 2020. The Ticker. https://www.traverseticker.com/news/city-to-use-eco-friendly-alternative-to-road-salt/

Table 31. Assessment of performance measure 19—salt usage

Submeasure	Findings	Rating	Likely Needs for Program
National Salt Usage for Roadway Maintenance Overall Rating— Strong Performance	Salt usage remains relatively constant at the national level, with mild winters causing dips in usage, suggesting that strategies for reducing salt use are not yet widespread enough to have an overall impact on use.	👊	The Road Weather Management Program (RWMP) should consider identifying State departments of transportation (DOTs) willing to volunteer to offer their State salt consumption statistics to correlate States' implementation of new snow and ice management approaches to reductions in salt usage.
Case Studies	There are examples of innovative and creative approaches to reducing salt usage. Over the coming years, these agencies will better understand the impacts of these approaches.	👍	Consider outreach activities to allow agencies with salt reduction approaches to share with other State DOTs. Track actual salt use by agencies adopting these approaches in future years performance management assessments

Diversity of Traffic Control Strategies

Diversity in response strategies was assessed under this measure (see figure 14). The 2021 survey included questions to understand the extent to which State DOTs are using traffic control strategies during inclement weather to improve safety and/or mobility. Analysis of the survey responses resulted in the following findings:

- **Traffic incident management strategies.** The most widely used response strategy was traffic incident management practices (e.g., quick clearance policies during inclement weather, staged freeway response vehicles, coordinated evacuations during hurricanes or flooding events). 46 percent of responders noted Statewide use and 39 percent reported limited or partial use (total use 85 percent).

- **Deploy ITS to Manage Traffic Diversions**. The use of ITS to manage traffic diversions was the next most selected strategy, with 27 percent of responders indicating Statewide use and 34 percent indicating partial or limited use (total use 61 percent).

- **Variable Speed Limits**. 10 percent of responders indicated they employ the use of variable speed limits based on real-time road weather conditions Statewide while 37 percent indicated limited areas or partial deployments (total use 47 percent).

- **Deploying ITS to Determine the Need for Vehicle Restrictions**. There was low reported use of deploying ITS to determine the need for temporary vehicle restrictions due to weather, with 10 percent of responders reporting Statewide use and 24 percent reporting partial or /limited use (total use 34 percent).

- **Signal Timing and Ramp Meters**. Responders indicated little use of adjusting signal timing and ramp meters due to inclement weather, with totals for both under 30 percent.

The results of each option described above are illustrated in table 32.

Two additional tools were included in the survey, where responders were asked to indicate their use as either Statewide, partial/limited, or none (figure 15).

- **Unmanned aerial systems (UAS) (i.e., drones).** Responders were asked to indicate their use of UAS to support data collection to assist road weather management activities. Ten percent of responders indicated Statewide use of drones while 17 percent indicated limited or partial use (total use 27 percent). Considering the innovative nature of UAS, this is a high usage.

- **Flood barrier systems.** Responders were asked to indicate their use of flood barrier systems (including inflatable barriers or sandbag barriers) to assist road weather management activities. 7 percent of responders indicated Statewide use while 15 percent indicated limited or partial use (total use 22 percent).
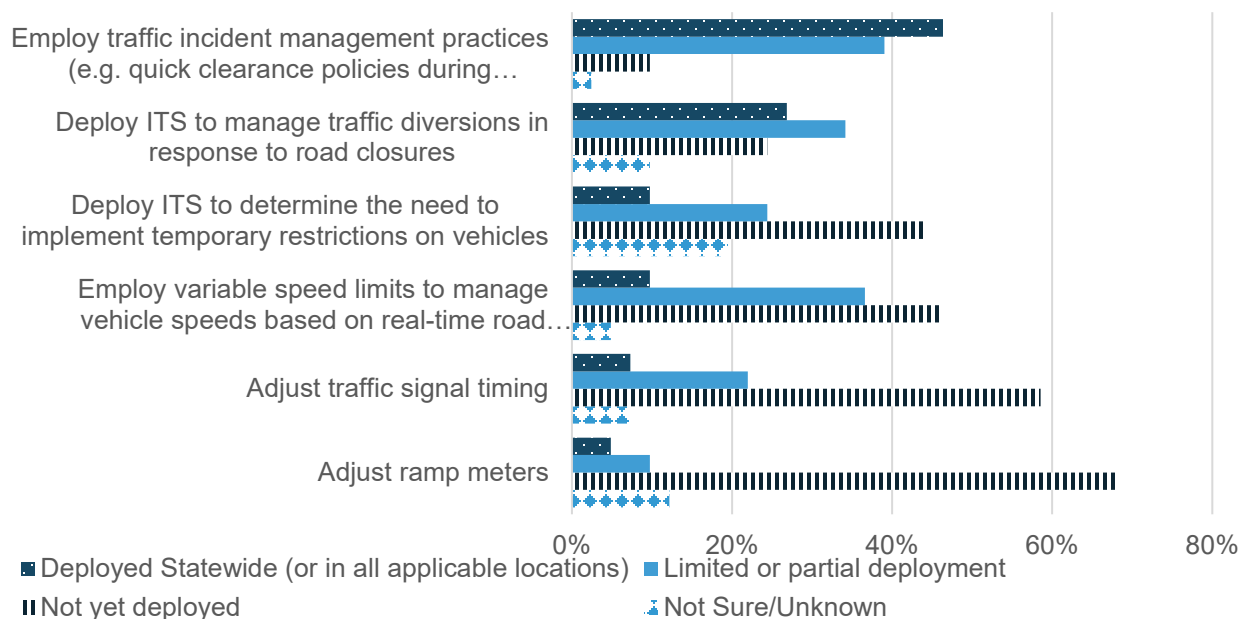
Figure 14. Graph. Survey responses noting the diversity of traffic control strategies
Source: Federal Highway Administration
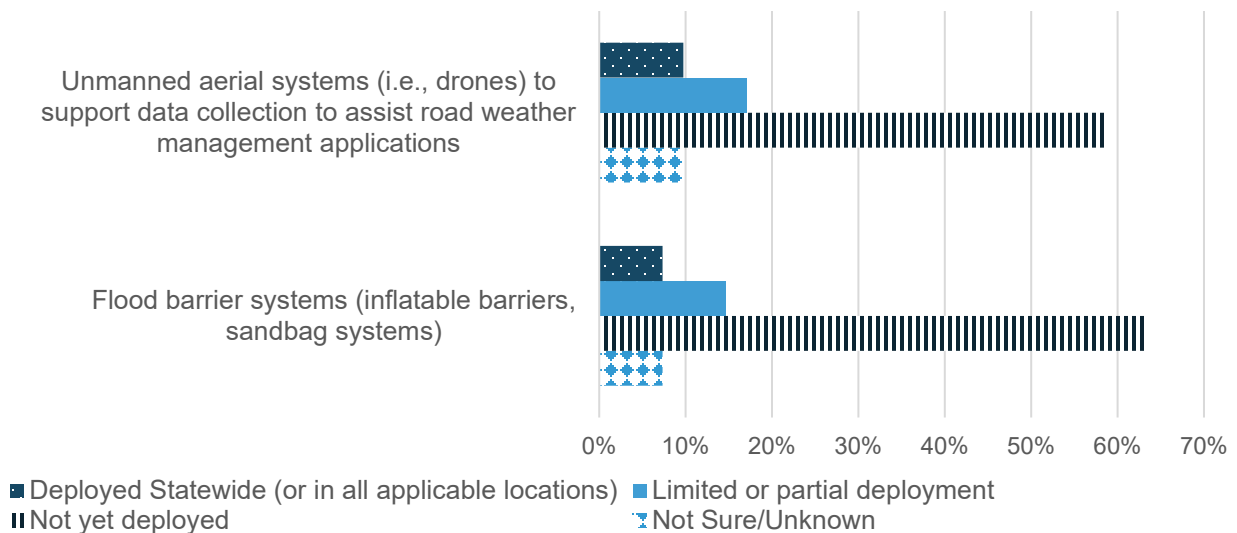
Figure 15. Graph. Survey responses on the real-time use of other tools for RWM activities
Source: Federal Highway Administration

Diversity of Innovative Road Treatment Strategies

Another aspect of this measure is the use of innovative road treatment strategies. The 2021 survey included questions to understand the extent to which State DOTs are using real-time data and/or decision support algorithms to determine road treatment strategies. Specifically, the survey asked questions about determining chemical application rates, routes for snowplows or chemical applications, and pre-treating roads for snow and ice.

- **Pre-treating roads.** The most common real-time use of data and/or decision support was to determine strategies for pre-treating roads, with 41 percent reporting Statewide use, and 29 percent reporting limited or partial deployment (total 70 percent reporting some use).

- **Chemical application rates.** The next most common real-time use of data and/or decision support was to determine strategies for chemical application rates, with 29 percent reporting Statewide use, and 29 percent reporting limited or partial deployment (total 58 percent reporting some use).

- **Snowplow or chemical application routes.** More than a third (34 percent) of States indicated real-time use of data and/or decision support algorithms are used on a Statewide basis, while 17 percent indicated partial or limited deployment (total 51 percent reporting some use).

Figure 16 illustrates the responses to the questions described above.
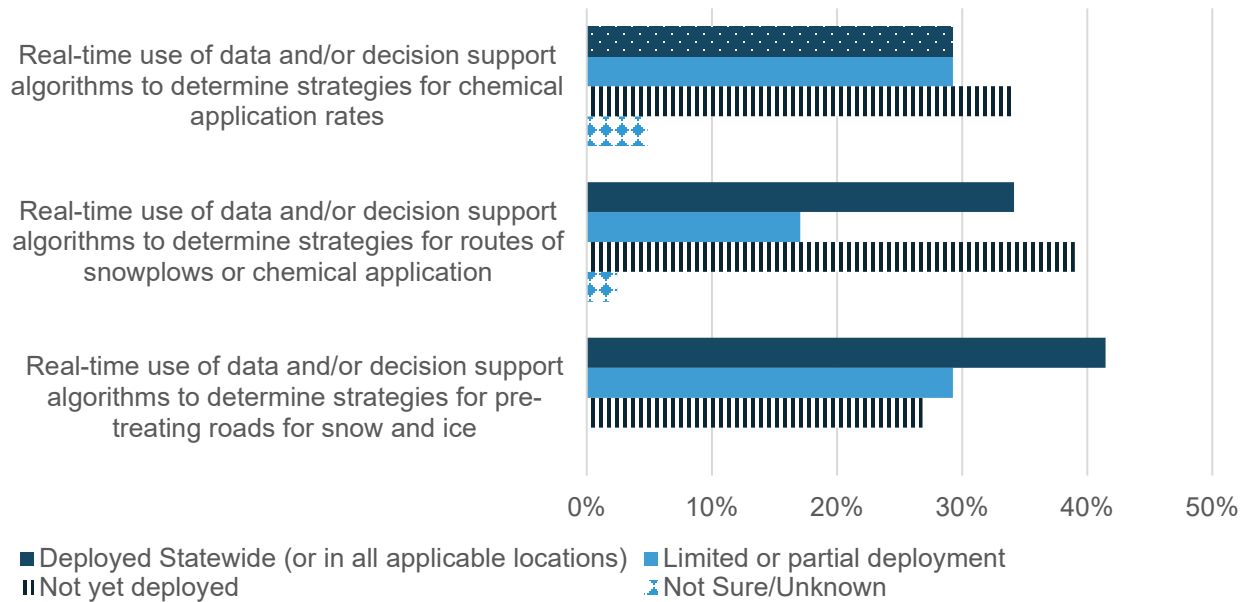
Figure 16. Graph. Survey responses on the real-time use of decision or support algorithms to determine response strategies
Source: Federal Highway Administration

Table 32 summarizes what has been learned by assessing this performance measure, including conclusions and likely needs for the RWMP.

Table 32. Assessment of performance measure 20—diversity of response strategies

Overall Rating—Strong Performance			
Submeasure	**Observations**	**Rating**	**Likely Needs for Program**
Use of Real-time Data and/or Decision Support for Road Treatment Strategies	More than half the responders use data and/or decision support for all three road treatment strategies queried (pre-treatment, chemical application rates, and routes for snowplows or chemical applications), while pre-treatment was the highest use of all three.	👍	The Road Weather Management Program (RWMP) should continue outreach activities in this regard as they have been successful. Consider additional topics in future outreach activities for determining route selection or chemical application rates.

Table 32. Assessment of performance measure 20—diversity of response strategies (continuation)

Overall Rating—Strong Performance			
Submeasure	**Observations**	**Rating**	**Likely Needs for Program**
Use of Innovative Traffic Management Strategies	There is high use of traffic incident management strategies, deploying intelligent transportation systems (ITS) to divert traffic, and variable speed limits during inclement weather, suggesting these strategies are well known and valued in the industry. About one-third of responders reported using ITS to determine the need for vehicle restrictions, and there was limited use of signal timing or ramp meter adjustments, suggesting the industry could benefit from more outreach and demonstrations of benefits for these.	👍	Consider outreach activities to allow agencies using ITS to determine vehicle restrictions to demonstrate these to other States. Consider working with traffic engineering groups to explore wider use of traffic management approaches to respond to weather events.
Use of Other Innovative Tools	Given how new unmanned aerial systems (UAS) are, the use by 27 percent of responders indicates this is an area that is growing fast and is of interest to State departments of transportation (DOTs). Innovative flood barriers are used less commonly, but that may be indicative of the fact that flooding impacts fewer agencies.	👍	Consider outreach activities to showcase UAS use and benefits. Consider discussion topics to understand if flooding is a concern to those sites that indicated they do not use innovative approaches to retain floodwaters.

State use of appropriate analysis tools to factor weather impacts and strategies

The activities that agencies perform to maintain the roads and manage traffic in response to weather events is not limited solely to the actions during the event, but rather can be represented as three periods of time:

- **Before weather events.** The time period when non real-time analysis tools can be used to determine procedures or policies for weather events. During this period, State DOTs can use a variety of modeling tools (e.g., microscopic, mesoscopic, etc.) to determine treatment strategies to use in later events.

- **During weather events.** This includes the time the weather event is happening through the time when clean-up is completed, and the road surface is returned to normal conditions. During this time, real-time tools can support the determination of both the maintenance activities to respond to the weather conditions and the traffic control activities to manage safe efficient travel during the event.

- **Post weather events.** During this period, tools can be used to conduct post-event analyses or road weather and traffic management actions to better prepare for future events. One example of such a tool was developed by the Clear Roads Pooled Fund Study (PFS) project titled

"Weather Event Reconstruction and Analysis Tool"[17] that developed a web-based tool to gather weather data for a specific time to support post analysis. In previous RWMP performance measurement analyses, survey questions asked responders about their use of appropriate analysis tools to factor weather impacts and strategies, with many options offered for responders to select from (e.g., microscopic simulation models, mesoscopic simulation models, travel demand analysis tools, etc.). In the 2019 assessment, nearly 50 percent of responders indicated "not sure/unknown", while approximately 14 percent indicated "traffic signal optimization tools" and 35 percent indicated "none."

This question was modified in the 2021 assessment with the intent of better capturing what analyses activities State DOTs are using by decreasing the "not sure/unknown" responses. Figure 17 illustrates the responses to the 2021 survey. 2019 and earlier responses did not break the question into the different periods, but all simulation and analysis tools received 3 percent of agencies reporting they used the tool.
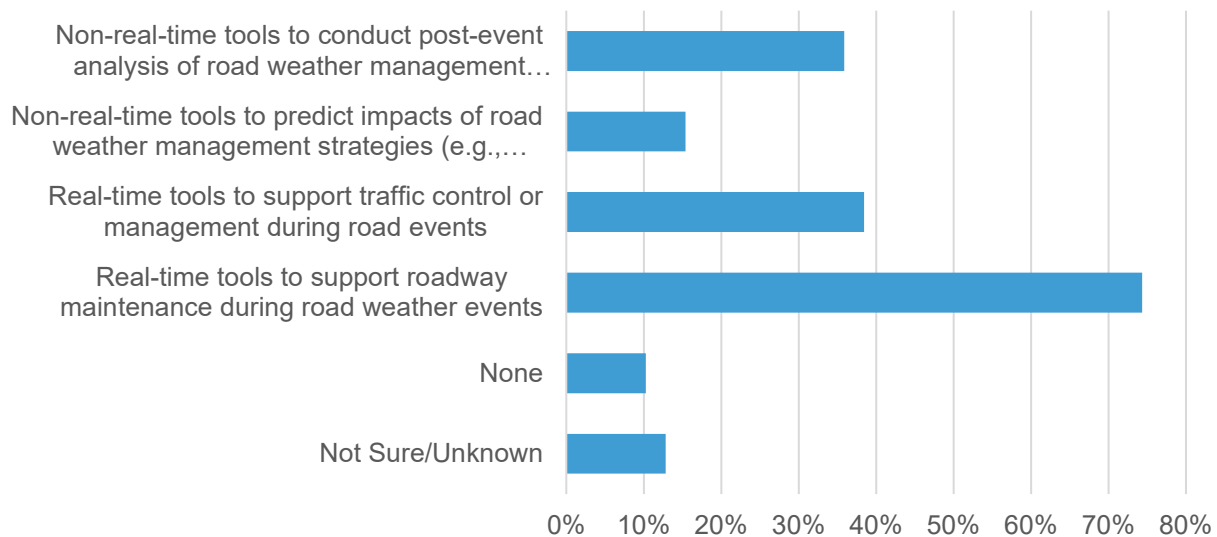
Figure 17. Graph. Percentage of State agencies using weather-responsive traffic analysis and simulation tools for planning and evaluating road weather management
Source: Federal Highway Administration

The results of the 2021 assessment are summarized as follows:

- **During weather events.** There is high usage of tools during weather events, with 80 percent of responders indicating they use real-time tools to support roadway maintenance and 35 percent indicating they use real-time tools to support traffic control or management during road events.

- **Post weather events.** 34 percent of State DOTs indicated the use of tools to conduct post analyses of weather events.

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[17] Weather Event Reconstruction and Analysis Tool. Clear Roads. https://clearroads.org/project/16-05/

- **Prior to weather events.** 15 percent of State DOTs indicated the use of tools to plan for future weather events. While this is the smallest, the 2019 survey identified only 3 percent of State DOTs reporting use of this type of modeling.

Table 33. Assessment of performance measure 21—agency use of tools

Overall Rating—Moderate Performance			
Submeasure	**Observations**	**Rating**	**Likely Needs for Program**
Real-time: Roadway Maintenance	There is strong use of real-time tools to support road maintenance activities during weather events, suggesting State departments of transportation (DOTs) benefit from this and that the Road Weather Management Program (RWMP) has been effective at encouraging and educating State DOTs about this critical activity.	👍	Continue this emphasis area as in the past.
Real-time: Traffic Control or Management	There is moderate use (33 percent of responders) of real-time tools to support traffic control or management during weather events.	✊	Consider additional outreach activities, potentially to reach the groups or individuals responsible for traffic management in the State DOTs
Post-event Analysis	There is moderate use (32 percent of responders) of tools to perform post-event analysis of weather management activities.	✊	Consider additional outreach activities to encourage more use of tools. Consider best practices and lessons learned sharing by agencies that indicated they use post-event analysis tools.
Prediction of Impacts of Road Weather Management (RWM) Strategies	There is limited use (15 percent of responders) of tools to predict impacts of road weather management strategies. This may suggest that these tools are less mature and/or that the benefits of using these tools are less known to the industry.	👎	The RWMP could consider increasing activities to understand the existence of these tools and then to demonstrate the use of them.

Participation in Climate Change Adaptation Planning

In the 2015, 2017, and 2019 surveys, responders were asked about their participation in State DOT climate change and/or adaptation planning activities. Survey questions allowed responders to either indicate they had participated, or they had not participated, or to indicate if they did not know for sure. In the 2021 survey, eight (8) responders indicated they had participated in adaptation planning, while seven (7) indicated they did not—resulting in 53 percent of known responses indicating participation in adaptation planning. Figure 18 represents the survey responses since 2015, comparing the percentage of known responses that have participated in adaptation planning. When the 2021 survey results are compared to previous survey results, the number of agencies reporting participation remains relatively constant, indicating there has not

been significant increases in the number of climate change and resilience adaptation planning or that survey responders are not aware of these activities in their agency.
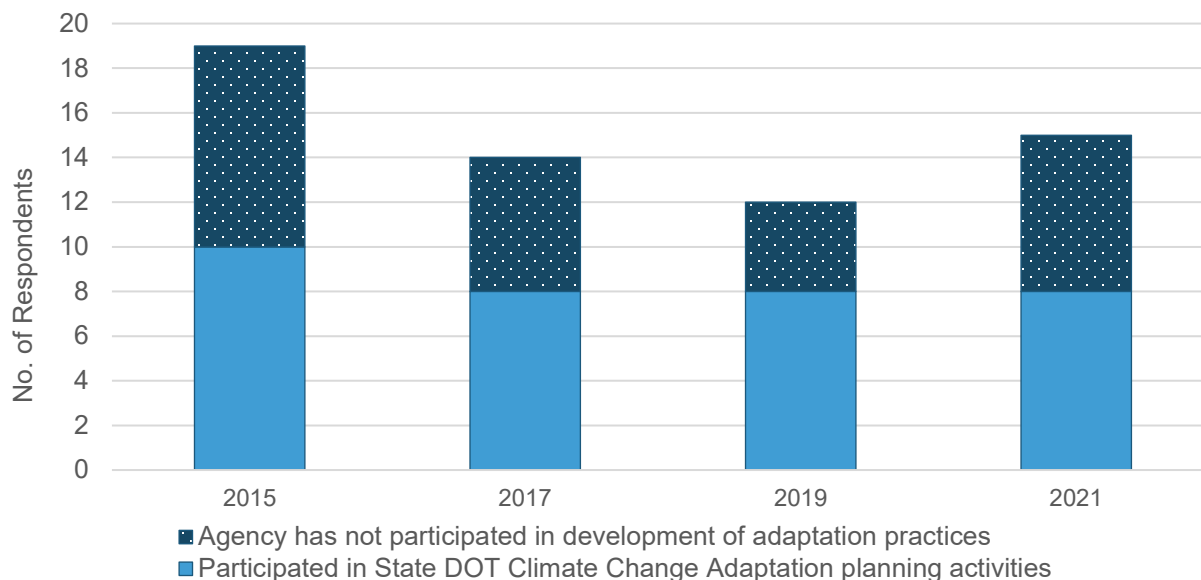
Note: Before 2019, the survey asked if States had participated in "resilience adaptation" planning.
Figure 18. Graph. Agency responses to participation in climate change/resilience adaptation processes, 2015–2021
Source: Federal Highway Administration

The individual responses to the 2021 surveys were analyzed more closely with the intent of understanding why positive responses to participating in adaptation planning are steady (or decreasing since 2015). This analysis revealed some additional insights:

- In the 2021 survey, nearly twice as many responders did not affirm either "yes" or "no" to participating in adaptation planning, but chose "unknown/not sure."

- Additionally, four States that responded yes to this question in 2019, answered "unknown/not sure" or did not answer the question in 2021.

- None of the responders who answered "yes" to this question in 2019 answered "no" in 2021.

Since the question is asking about the agencies' past participation in adaptation planning, it is unlikely that an agency that previously had participated would now indicate that they have not participated in the past, which was confirmed in that there were no States that previously indicated participation and now indicate no participation. However, the four States that previously noted participation and now indicate "unsure/not know/no answer" suggests gaps in the understanding of survey responders to their agency activities in adaptation planning, such as through attrition or different individuals responding to the surveys. Table 34 summarizes the findings.

Table 34. Assessment of performance measure 22—climate change and extreme weather

Overall Rating—Moderate Performance			
Submeasure	**Observations**	**Rating**	**Likely Needs for Program**
State Department of Transportation (DOT) Participation in Climate Change Adaptation Planning	More than half of the responders aware of their agency's status confirmed they have participated in climate change adaptation planning, however this number is not a significant change over earlier years, and suggests more agencies would benefit from this planning.	👊	Consider new activities to re-introduce climate change adaptation planning to encourage more agencies to participate
State DOT Knowledge of Whether They Have Participated in Climate Change Adaptation Planning	About half of responders did not know if their agency had participated in climate change adaptation planning, and four agencies that previously responded "yes" now responded that they were not sure. This suggests that the individuals' knowledge about adaptation planning varies and States might benefit from refresher exercises to encourage internal sharing of previous planning activities.	👎	Consider best practice sharing by State DOTs about their climate change adaptive planning practices, and compiling a list of agencies that have previously indicated they have performed adaptive planning, to share across all States.
Preparation of Extreme Weather Response Processes	Fifty-seven percent of responders aware of their agency's status confirmed they have developed or implemented extreme weather response processes. Six agencies that had not previously confirmed this action now confirmed it, suggesting that agencies probably are still implementing these activities. The fact that 43 percent of responders confirmed they have not developed or implemented extreme weather response processes suggests there is still work to do to encourage and assist agencies in taking this step.	👊	Consider new activities to reintroduce the development of extreme weather process development, focusing initially on those six agencies that indicated they have not completed this.
State DOT Knowledge of Whether They Have Participated Extreme Weather Process Development	Approximately half of the responders did not know if their agency has developed/implemented extreme weather processes. This suggests that the individuals' knowledge about activities surrounding extreme weather vary greatly.	👎	Consider best practice sharing by State DOTs about their extreme weather process development and implementation, and compiling a list of agencies that have previously indicated they have developed and implemented these processes to share the outcomes with other States.

Table 34. Assessment of performance measure 22—climate change and extreme weather (continuation)

Overall Rating—Moderate Performance			
Submeasure	**Observations**	**Rating**	**Likely Needs for Program**
Vulnerability/Risk Assessment Understanding for RWM Infrastructure	Less than 30 percent (and no increase from 2019) of responders indicated they have conducted vulnerability/risk assessment for the RWM infrastructure. This suggests the risks and vulnerabilities are not well understood.	👎	Consider new activities to encourage vulnerability and risk assessment of RWM infrastructure, perhaps through sessions in annual RWM meetings or through special webinars.
Resilience Planning for RWM Infrastructure	Less than 20 percent (and a decrease from 2019) of responders indicated they have developed resilience plans for RWM infrastructure. This suggests that few State DOTs have resilience plans for RWM infrastructure and implies levels of vulnerability are possible.	👎	Consider new activities to encourage resilience planning for RWM infrastructure, perhaps through sessions in annual RWM meetings or through special webinars.

Extreme Weather Response Preparation

Previous surveys asked responders to check a box if they had developed or implemented a process to respond to extreme weather, although there was no option to indicate if the agency had not developed extreme weather processes. The percentage of responders indicating they did implement this process increased between 2015 and 2017, but declined in 2019. To understand the responses, an option was added to the 2021 survey giving responders the option to indicate whether or not they had developed or implemented an extreme weather response process. In the 2021 survey, 12 responders indicated they had developed or implemented extreme weather response processes, while 9 responders indicated they had not—resulting in 57 percent of known responses (i.e., agencies that either answered "yes" or "no" instead of "not sure/unknown"). Figure 19 represents the 2021 survey responses. No comparison is made to earlier responses because of the question added to the 2021 survey.
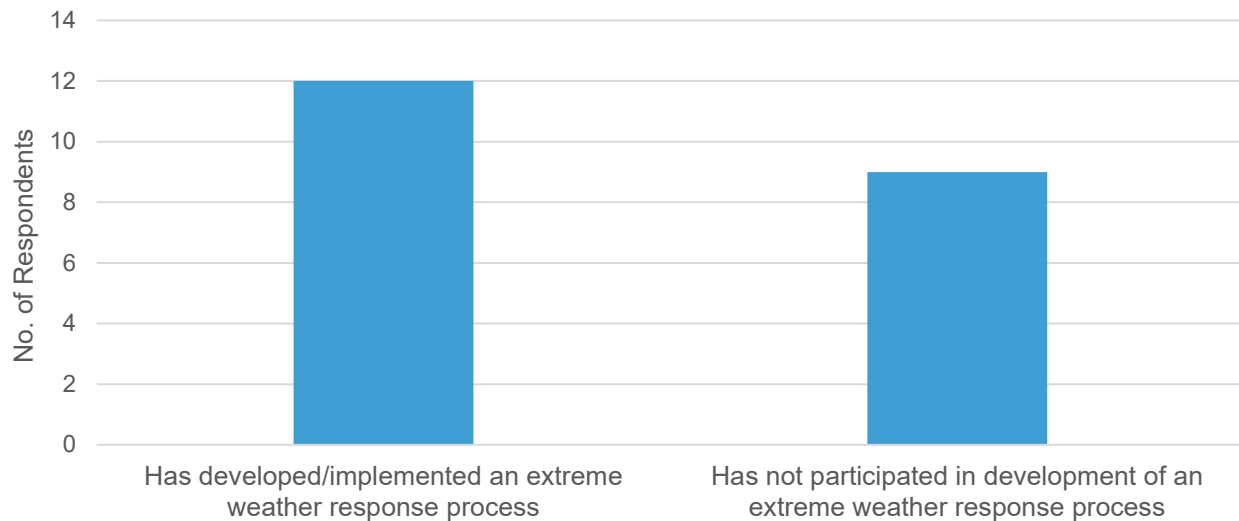
Figure 19. Graph. Survey responses for number of respondents indicating whether they have or have not developed an agency response to extreme weather process.
Source: Federal Highway Administration

Vulnerability/risk assessment and resiliency plans for RWM infrastructure

The FHWA Order 5520[18] defines resilience as "the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions". Resilience planning involves understanding the threats to systems deployed (e.g., recurring storms, weather changes, etc.) and the identification of actions to mitigate the risks caused by these.

Two options in the survey asked responders to indicate their status of vulnerability/risk assessment and resilience planning. Figure 20 illustrates the responses over the past four surveys. The percentage of State DOTs that conducted vulnerability/risk assessments for RWM infrastructure remained the same from the 2019 survey, but is still below 25 percent.

The percentage of State DOTs that have developed/implemented resiliency plans for RWM infrastructure declined in 2021 (a reduction from 28 percent to 18 percent). After further analyzing the data, four agencies that indicated in 2019 that they have developed/implemented resiliency plans for RWM selected "not sure/unknown" in the 2021 survey, suggesting that it is likely a different individual without knowledge of previous activities or confusion over the question caused the decrease. The percentage in 2019 was 28 percent and in 2021 is less than 20 percent.

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[18] FHWA Order 5520. "Transportation System Preparedness and Resilience to Climate Change and Extreme Weather Events." December 15, 2014, https://www.fhwa.dot.gov/legsregs/directives/orders/5520.cfm
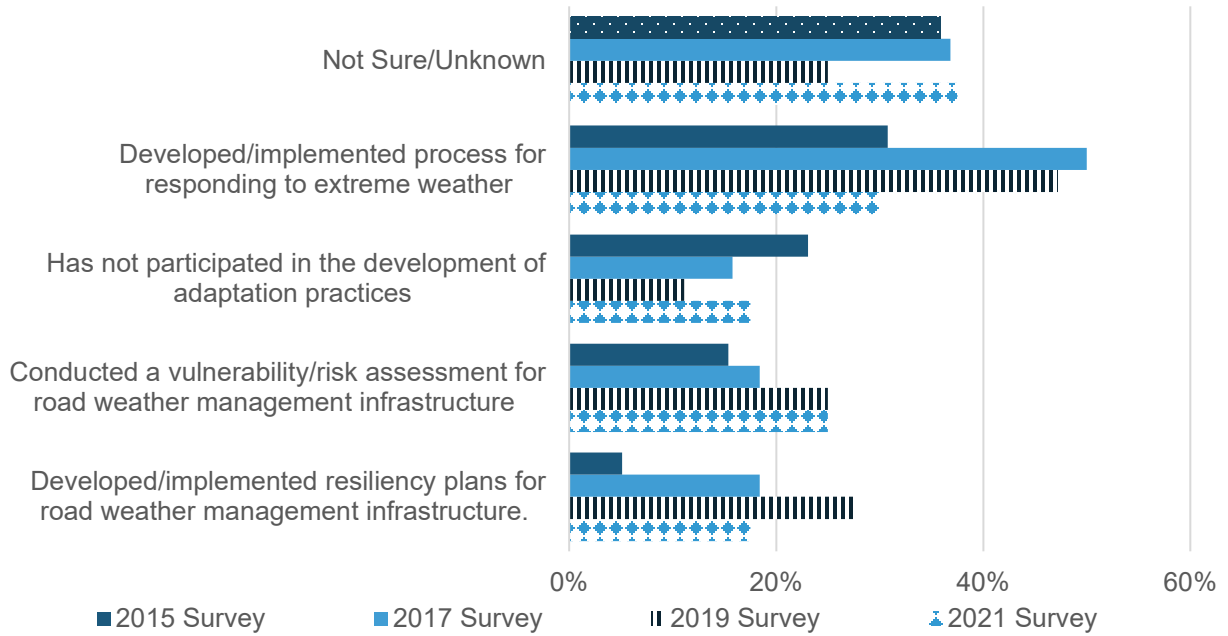
Figure 20. Graph. Survey responses to vulnerability and resilience preparation activity questions, 2015–2021

Source: Federal Highway Administration

7. Conclusions

In general, the 2021 performance measures assessment indicated strong performance by the Road Weather Management Program (RWMP) in accomplishing the objectives of the program. While analysis of specific performance measures revealed some areas and topics that the RWMP could better emphasize, the findings broadly point to successes of the RWMP. As such, the primary likely need for the RWMP is to continue outreach and engagement efforts to State departments of transportation (DOTs), as these have clearly been successful for advancing the RWMP objectives. Additionally, the RWMP may use the findings of this analysis to identify and prioritize specific areas and topics to highlight or emphasize as part of future outreach and engagement efforts.

Another likely need for the RWMP is to re-examine efforts related to Innovation, Resilience and Sustainability for Objective 5. While innovation-related performance showed positive impacts, resilience and sustainability were not as favorable. A likely need therefore is that the RWMP reach out to agencies to understand whether resilience and sustainability should continue to be focus areas for the program, and if so, potentially explore the initiation of new outreach and engagement activities in these areas.

The 2021 update includes the following tactical likely needs to support day-to-day, activities and areas of strength for the RWMP as well as to help those areas with moderate or lower performance to grow. These are intended to be comprehensive based on the findings of this effort. It is expected that the RWMP will prioritize the items of greatest interest for agencies and importance to the RWMP objectives, as it is likely not realistic to pursue all of the activities identified below.

RWMP-sponsored webinars. Given the strong and sustained level of participation for RWMP webinars during this review cycle, there is a likely need for Federal Highway Administration (FHWA) to continue to conduct webinars on a regular basis to promote education and best practices. The FHWA should examine gaps identified in this effort to consider these as webinar topics and also continue to work with agencies to identify topics of interest for these webinars. Topics for further exploration include:

- **Benefits of Innovative Road Weather Products and Services.** This could include mobile agency sensors, crowdsourcing, and social media to promote and expand their use across State DOTs.

- **Benefits of expanding mobile observation data collection and innovative uses.** This would support broader agency uses for all types of mobile data as few agencies collect data for all fleet vehicles.

- **New and innovative ways that agencies are using environmental sensor stations (ESS).** This would encourage greater agency use, as there is potential for many agencies to better leverage their ESS in new ways beyond their current practices.

- **Vulnerability/risk assessment for road weather management (RWM) infrastructure.** This would explore the basics around risks and vulnerabilities to encourage the use of assessments by State DOTs.

- **Resilience Plans for RWM infrastructure.** This would explore the basics for creating resilience plans to encourage agency creation of plans to protect infrastructure.

RWMP technical assistance. Several examples were identified in which additional technical assistance and/or RWMP support is likely needed to help enhance agency road weather management and operations. Specific topics include:

- **RWMP research and development (R&D) projects.** Rising participation levels across FHWA R&D projects (Pathfinder, Weather Responsive Management Strategies (WRMS), Weather Data Environment (WxDE)) indicate a continued, strong interest in these initiatives. The RWMP should continue to work with agencies to move these projects from research to standard agency operations.

- **Connectivity and automation R&D.** Nearly half of agency survey respondents indicated they are conducting activities (i.e., research, demonstrations, tests, deployments) that support the use of infrastructure to broadcast information to support in-vehicle RWM applications and messaging. The RWMP should continue to support these efforts through technical assistance and grant opportunities, as available.

- **Automated Decision Making and vehicle automation.** Out of the five RWM focus areas/trends to occur over the next 5 to 10 years, automated decision making and vehicle automation were the two included least across the RWMP activities. It is a likely need that the RWMP work with State agencies and research institutions to identify pilots and other use cases of innovation across these two focus areas to enable more discussion and understanding of the topics.

RWMP-sponsored workshops, peer exchanges, and demonstration site visits. Events that enable peer-to-peer information exchange and lessons learned have been proven to impact the deployment of RWM strategies. As such, it is a likely need that the RWMP conduct events focused on the following topic areas:

- **Use of connectivity and automation in RWM and strategic planning.** Most States surveyed noted they are considering the use of applications to gather and use mobile road weather data. It is a likely need that the RWMP nurture this interest through events (e.g., peer exchanges, site visits) to enable the sharing of ideas and lessons learned between early adopters and interested States.

- **Use of traditional and innovative products and services to increase situational awareness.** Conducting workshops and peer exchanges will promote the benefits of innovative products like mobile agency sensors, crowdsourcing, and social media. Meanwhile, it is a likely need that the RWMP reach out and/or conduct workshops with those few DOTs that do not use traditional products to better understand their current practices and promote these offerings.

- **Use of ESS.** Consider reaching out to agencies that have few or no ESS to understand why ESS are not deployed through targeted calls or workshop sessions.

- **Use of mobile-data application.** given the decline in application development noted under this assessment, it is a likely need that activities such as peer exchanges or workshops be conducted to facilitate the sharing of developed applications between agencies to encourage greater agency use.

- **Dissemination of weather information.** As the number of agencies deploying safety warning systems for road weather conditions continue to rise it is a likely need that workshops or peer exchanges be conducted to continue sharing best practices and innovative deployments to encourage broader agency use.

- **Decision support systems.** Similarly, it is a likely need that events be conducted to encourage broader agency use of decision support systems as the number of agencies remain similar to the 2019 update.

- **Unmanned Aerial Systems.** There is a strong and growing interest in this new, innovative technology. The RWMP may consider additional outreach activities to showcase unmanned aerial systems (UAS) use and benefits.

- **Post-event analysis.** Given the moderate use of tools to perform post-event analysis of weather management activities, it is suggested that sharing of lessons learned be conducted for agencies on their current practices to encourage broader use.

- **Climate change.** Half of survey respondents did not know whether their agencies had participated in climate change adaptation planning or whether they had developed extreme weather processes, suggesting an event for best practice sharing may be warranted.

Data collection activities. In addition to the engagement and outreach activities described above, there are instances across the assessment in which additional data collection would support enhanced RWM. A specific example relates to salt usage. Salt usage remains relatively constant at the national level, with mild winters causing dips in usage, suggesting that strategies for reducing salt use are not yet widespread enough to have an overall impact on use. It is a likely need that the RWMP identify State DOTs willing to volunteer to offer their State salt consumption statistics to correlate States' implementation of new snow and ice management approaches to reductions in salt usage. Additionally, there are examples of innovative and creative approaches to reducing salt usage. Over the coming years, these agencies will better understand the impacts of these approaches. The RWMP should consider tracking actual salt usage by agencies adopting these approaches in future assessment periods. Similarly, the RWMP should continue working with agencies to promote the contribution to, and use of, the WxDE.

New RWMP activities and projects. Findings indicate the importance of developing new activities and/or projects focused on weather impact analysis tools and climate change, assuming

these two topics continue to be a focus area for the RWMP. Specifically, it is a likely need that the following topics be considered for "new" activities:

- **Prediction of impacts of RWMP strategies.** This includes activities focused on understanding the availability of these tools and how to use them.

- **Climate change adaptation planning.** this includes activities to re-introduce climate change adaptation planning to agencies.

- **Preparing for extreme weather.** This includes activities to re-introduce extreme weather process development to agencies.

- **Vulnerability risk assessment.** This includes activities to encourage the use of vulnerability and risk assessment of RWM infrastructure.

- **Resilience planning.** This includes activities to promote the use of resilience planning for RWM infrastructure.

Industry meetings and conferences. Findings indicate consistently strong participation across the industry and by State agencies at public activities in which the RWMP is either attending, presenting, or moderating. As such, it is a likely need that the RWMP continue to work with organizational champions to maintain momentum in promoting the RWMP initiatives across national and international activities (e.g., meetings, workshops, conferences, events). Specific RWM session topics for further exploration include:

- **Use of Connected vehicles and automated driving capabilities.** The majority of surveyed agencies indicated an interest in talking with external organizations about connectivity and automation to support RWM.

- **Non-USDOT-sponsored R&D.** Most surveyed agencies noted that they have or are currently collaborating with other groups to conduct R&D research.

- **Use of innovative traffic management strategies.** specifically, this involves having agencies work with traffic engineering groups to explore wider use of traffic management approaches to response to weather events.

RWMP outreach activities. There are several instances in which additional outreach (i.e., fact sheets, case studies, emails, newsletters) would be useful to provide agencies and industry stakeholders with information on a variety of the RWMP topics. These include:

- Participation in WxDE.
- Connectivity and Automation to Support Road Weather Management.
- Use of Innovative Products and Services to Increase Situational Awareness.
- Collection and use of Mobile Observations.
- Use of Mobile-Data Applications.
- Benefits of ESS.
- Safety Warning Systems for Disseminating of Weather Information.

- Pathfinder/Collaboration with the National Weather Service (NWS).
- Decision Support Systems.
- RWMP's Revamped National Highway Institute (NHI) Training Course.
- RWMP's RWM Capability Maturity Framework (CMF) Assessment.
- Use of Real-Time Data/Decision Support for Road Treatment.
- Use of Innovative Traffic Management Strategies.
- Use of UAS.
- Real-Time Traffic Control Management.
- Post-Event Analysis.

Appendix A. States' Answers to Survey

Survey questions are given in this appendix with tables summarizing the States' answers. Note that question 1 asked participants to enter their name, State, and email address; question 2 asked participants for the name and email address for the manager of the transportation management center (TMC), or the most appropriate TMC contact if the agency operates multiple TMCs.

Q3. What are your agency's sources of weather and road weather information? (check all that apply)

Related performance measure (PM): PM 8. Number of State DOTs that subscribe to road weather products and services

Table 35. Survey question 3 and associated responses

Answer Options	No.	Percentage
USGS Earthquake Alerts	6	15%
MADIS (Meteorological Assimilation Data Ingest System)	5	12%
FHWA's WxDE (Weather Data Environment)	2	5%
FAA Products (automated surface observing system [ASOS], automated weather observing system [AWOS], etc.)	11	27%
Mobile Data Sources	27	66%
Traditional Media Sources (television, radio, newspaper, etc.)	29	71%
Social Media (Facebook, Twitter, etc.)	19	46%
Crowdsourced data (citizen reporters, Waze, etc.)	16	39%
Private Weather Service Providers	31	76%
Agency Staff Meteorologist	6	15%
Agency Field Personnel	27	66%
Agency Sensors (road weather information system [RWIS] and environmental sensor station [ESS] probes)	38	93%
National Weather Service Products	38	93%
Not Sure/Unknown	0	0%
Other (please specify)	5	12%

- No. of respondents who answered question: 41
- No. of respondents who skipped question: 0

Other (please specify) responses:
- MDSS DTN Product and Pooled Fund Study
- State Environmental Mesonet (which would include Madis and WxDE indirectly
- State Emergency Management
- Even though we have agreements in place with MADIS and the WxDE along with mobile data sources, the Department of Transportation has taken a step back to gather all the departments needs and develop an RFP for a common telematics platform. That is still under development.
- Contract with University Meteorological department

Q4. Does your agency collect real-time data from agency-operated fleet vehicles (e.g., snowplows, supervisor trucks, spreaders, etc.) that are used to support road weather management activities?

Related PM: PM#9. Number of State DOTs collecting mobile observations of road weather data from vehicle fleets

Table 36. Survey question 4 and associated responses

Answer Options	No.	Percentage
Yes	34	83%
No	7	17%

- No. of respondents who answered question: 41
- No. of respondents who skipped question: 0

Q5. Which of the following data are collected from agency-operated fleet vehicles, and from what percentage of the applicable fleets?

Related PM: PM#9. Number of State DOTs collecting mobile observations of road weather data from vehicle fleets

Table 37. Survey question 5 and associated responses

Data Type	100%		At least 50% but less than 100%		At least 25% but less than 50%		Less than 25%		Not Collected		Not sure/ Unknown		Total No.
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
Plow Status and Material Usage	5	15%	14	41%	2	6%	9	26%	2	6%	2	6%	34
Atmospheric Weather Data[1]	2	6%	9	27%	4	12%	14	42%	3	9%	1	3%	33
Road Weather Condition Data[2]	4	12%	10	29%	3	9%	12	35%	4	12%	1	3%	34
Road Images or Videos from Dashboard Cams	3	9%	4	12%	1	3%	14	41%	12	35%	0	0%	34

[1]Examples: Air temperature, relative humidity
[2]Examples: Pavement temperature, condition (snow covered, wet)

- No. of respondents who answered question: 34
- No. of respondents who skipped question: 7

Q6. How many permanent environmental sensor stations (ESS) (i.e., Road Weather Information System (RWIS) Stations) does your State agency operate Statewide? (total number)

Related PM: PM#10. Number of State DOTs reporting the use of Environmental Sensor Stations (ESS) in operations and maintenance activities

Table 38. Survey question 6 and associated responses

Range of Answers Given	No.	Percentage
None	2	5%
1—49 permanent ESS	17	41%
50—99 permanent ESS	10	24%
100—149 permanent ESS	8	20%
150—199 permanent ESS	4	10%

- No. of respondents who answered question: 41
- No. of respondents who skipped question: 0

Q7. How many transportable ESS (i.e., ESS that may be moved and set up in locations where weather/road condition monitoring is needed, such as work zones or other areas requiring temporary weather monitoring) does your State agency operate Statewide? (total number)

Related PM: PM#10. Number of State DOTs reporting the use of Environmental Sensor Stations (ESS) in operations and maintenance activities

Table 39. Survey question 7 and associated responses

Range of Answers Given	No.	Percentage
0 transportable ESS	32	82%
1 transportable ESS	1	3%
3 transportable ESS	2	5%
4 transportable ESS	1	3%
5 transportable ESS	1	3%
10 transportable ESS	2	5%

- No. of respondents who answered question: 39
- No. of respondents who skipped question: 2

Q8. How many mobile sensors (i.e. sensors installed on vehicles such as snowplows or maintenance vehicles, collecting data as the vehicle moves) does your State agency operate on agency vehicles Statewide? (total number)

Related PM: PM#10. Number of State DOTs reporting the use of Environmental Sensor Stations (ESS) in operations and maintenance activities

Table 40. Survey question 8 and associated responses

Range of Answers Given	No.	Percentage
0 mobile sensors	14	35%
1-99 mobile sensors	11	28%
100-199 mobile sensors	3	8%
200-299 mobile sensors	3	8%
300-399 mobile sensors	1	3%
400-499 mobile sensors	2	5%
500-599 mobile sensors	1	3%
600-699 mobile sensors	1	3%
700-799 mobile sensors	0	0%
800-899 mobile sensors	1	3%
900-999 mobile sensors	0	0%
1000-2000 mobile sensors	2	5%
Over 2000 mobile sensors	1	3%

- No. of respondents who answered question: 40
- No. of respondents who skipped question: 1

Q9. Describe how you use your ESS (check all that apply).

Related PM: PM#10. Number of State DOTs reporting the use of Environmental Sensor Stations (ESS) in operations and maintenance activities

Table 41. Survey question 9 and associated responses

Answer Options	No.	Percentage
Use ESS data to provide current conditions to traveler information systems	31	78%
Use ESS data as input for segment-level forecasts	22	55%
Use ESS data during winter weather events to support traffic management and maintenance decision-making	35	88%
Use ESS data during non-winter weather events to support traffic management and maintenance decision-making (e.g., monitoring wind when performing weed control, monitoring rain when performing pavement repairs, monitoring water levels for flood control)	20	50%
Not Sure/Unknown	7	18%
Other (please specify)	6	15%

- No. of respondents who answered question: 40
- No. of respondents who skipped question: 1

Other (please specify) responses:

- Performance measurement tools
- None available
- Feed to NWS
- We use it as our lone source of info for the DOT Snow and Ice Metric
- ESS definition isn't clear. RWIS or mobile road temp sensor?
- Use ESS to determine appropriate speeds on variable speed limit systems

Q10. Has your agency developed applications or tools that rely on the availability of real-time mobile data from agency fleet vehicles and/or vehicle-to-infrastructure (V2I) connectivity? (select one)

Related PMs:
- PM#5. Number of agencies researching the role of connected and automated vehicles in road weather management
- PM#11. Number of/percentage of responding agencies using mobile data-based applications in road weather management

Table 42. Survey question 10 and associated responses

Answer Options	No.	Percentage
Developed applications that use both real-time data from agency fleet vehicles and V2I connectivity	7	17%
Developed applications that use real-time data from agency fleet vehicles	6	15%
Considering applications in either area, but not yet developed	22	54%
Not Sure/Unknown	6	15%

- No. of respondents who answered question: 41
- No. of respondents who skipped question: 0

Q11. V2I connectivity has the potential to support collection of road weather data on a vehicle and communication of this data to the DOT for processing. Similarly, V2I connectivity has the potential to communicate data from the DOT to the vehicle for use by the driver or in-vehicle applications. Has your agency developed (or is developing) a strategic plan or similar documentation that includes consideration of any of the following? (select all that apply)

Related PM: PM#5. Number of agencies researching the role of connected and automated vehicles in road weather management

Table 43. Survey question 11 and associated responses

Answer Options	No.	Percentage
The role of V2I connectivity as it relates to road weather management and agency fleet vehicles	17	41%
The role of V2I connectivity as it relates to road weather management and private vehicles	8	20%
Not Sure/Unknown	11	27%
None of the Above	12	29%

- No. of respondents who answered question: 41
- No. of respondents who skipped question: 0

Q12. Partial or full driving automation has the potential to perform some or all of the driving tasks automatically. This could impact agency fleet vehicles (e.g., partially or fully operated vehicles performing road weather treatment) or private vehicles (e.g., in-vehicle applications that receive and process road weather data to support the automated driving tasks of the vehicle). Has your agency developed (or is developing) a strategic plan or similar documentation that includes consideration of any of the following? (select all that apply)

Related PM: PM#5. Number of agencies researching the role of connected and automated vehicles in road weather management

Table 44. Survey question 12 and associated responses

Answer Options	No.	Percentage
The role of partially automated or fully automated driving capabilities as it relates to road weather management and agency fleet vehicles	11	27%
The role of partially automated or fully automated driving capabilities as it relates to road weather management and private vehicles	8	20%
Not Sure/Unknown	14	34%
None of the Above	15	37%

- No. of respondents who answered question: 41
- No. of respondents who skipped question: 0

Q13. Has your agency participated in associations, working groups, pooled fund studies, or other organizations that include discussions of road weather management and any of the following? (select all that apply)

Related PM: PM#5. Number of agencies researching the role of connected and automated vehicles in road weather management

Table 45. Survey question 13 and associated responses

Answer Options	No.	Percentage
Connected vehicles	28	68%
Partially automated or fully automated driving capabilities	25	61%
Not Sure/Unknown	7	17%
None of the above	4	10%

- No. of respondents who answered question: 41
- No. of respondents who skipped question: 0

Q14. Has your agency conducted (or is conducting) research projects, demonstrations, tests, or deployments that use infrastructure to broadcast data or information to support in-vehicle road weather management applications or messaging?

Related PM: PM#5. Number of agencies researching the role of connected and automated vehicles in road weather management

Table 46. Survey question 14 and associated responses

Answer Options	No.	Percentage
Yes	19	46%
No	12	29%
Not Sure/Unknown	10	24%
Other	0	0%

- No. of respondents who answered question: 41
- No. of respondents who skipped question: 0

Q15. Describe the level of deployment in your agency of the following road weather information strategies.

Related PM: PM#12. Number of States disseminating advisory weather and road weather information to travelers

Table 47. Survey question 15 and associated responses

Road Weather Information Strategies	Deployed Statewide (or in all applicable locations)		Limited or Partial Deployment		Not Yet Deployed		Not Sure/ Unknown		Total
	No.	%	No.	%	No.	%	No.	%	No.
Atmospheric weather information on dynamic message signs	22	54%	7	17%	10	24%	2	5%	41
Road condition information on dynamic message signs	24	59%	13	32%	4	10%	0	0%	41
Road condition information on highway advisory radio	8	20%	8	20%	17	41%	8	20%	41
Road condition information on agency-hosted social media (Twitter, Facebook, etc.) or mobile applications	30	73%	6	15%	5	12%	0	0%	41
Road condition information on agency hosted websites or 511 phone systems	35	85%	2	5%	3	7%	1	2%	41
Weather or road condition information messaging in coordination with NWS (collaboration for consistent messaging) for winter weather events	20	50%	12	30%	6	15%	2	5%	40
Weather or road condition information messaging in coordination with NWS (collaboration for consistent messaging) for non-winter weather events	16	39%	12	29%	11	27%	2	5%	41

- No. of respondents who answered question: 41
- No. of respondents who skipped question: 0

Q16. Was your agency's decision to deploy any of the road weather information strategies identified influenced by FHWA's Pathfinder initiative?

Related PM: PM#12. Number of States disseminating advisory weather and road weather information to travelers

Table 48. Survey question 16 and associated responses

Answer Options	No.	Percentage
Yes	25	61%
No	6	15%
Not Sure/Unknown	10	24%

- No. of respondents who answered question: 41
- No. of respondents who skipped question: 0

Q17. Describe your level of interaction with the National Weather Service (NWS) local forecast offices for road weather management and operations activities. (check all that apply)

Related PMs:
- PM#12. Number of States disseminating advisory weather and road weather information to travelers
- PM#13. Number of agencies that coordinate with their local forecast offices for road weather management and operations

Table 49. Survey question 15 and associated responses

Answer Options	No.	Percentage
Rely only on publicly available information via media and NWS, there is limited to no coordination with NWS	8	20%
Starting to work with local NWS offices and other weather agencies, but limited to major events	11	28%
Routine coordination with NWS during the winter weather season. Have access to meteorological expertise to assist with decision making for most events	25	63%
Routine coordination with NWS during the non-winter weather seasons. Have access to meteorological expertise to assist with decision making for events such as flooding, severe wind or rain	22	55%
Not Sure/Unknown	0	0%

- No. of respondents who answered question: 40
- No. of respondents who skipped question: 1

Q18. Has your agency deployed safety warning systems (e.g., dynamic roadside signs or static signs with beacons, variable speed limit systems) related to any of the following road weather events? (check all that apply)

Related PM: PM#12. Number of States disseminating advisory weather and road weather information to travelers

Table 50. Survey question 18 and associated responses

Answer Options	No.	Percentage
Icy Roads	21	51%
Flooding	17	41%
Fog	13	32%
Wind	18	44%
Dust	7	17%
No	11	27%
Not Sure/Unknown	1	2%
Other (please specify)	5	12%

- No. of respondents who answered question: 41
- No. of respondents who skipped question: 0

Other (please specify) responses:
- Winter conditions
- Blowing Snow, Snow Squalls
- We utilize existing ITS infrastructure
- Low visibility due to snow squalls.
- Ski slope snowmaking

Q19. In what ways does your agency use decision support tools for road weather management? (check all that apply)

Related PM: PM#14. Number of agencies adopting MDSS technologies and methods

Table 51. Survey question 19 and associated responses

Answer Options	No.	Percentage
Do not use decision support tools	6	20%
Provides traveler information	16	53%
Coordinates with other jurisdictions/agencies	13	43%
Supports winter maintenance activities (e.g., maintenance scheduling, plow routing, material application)	20	67%
Supports non-winter maintenance activities (e.g., maintenance scheduling, construction coordination)	14	47%
Supports traffic control and management activities (e.g., speed limit determination, signal timing plans, ramp metering rates)	11	37%
Sets seasonal load restrictions	4	13%
Not Sure/Unknown	0	0%
Other (please specify)	6	20%

- No. of respondents who answered question: 30
- No. of respondents who skipped question: 11

Other (please specify) responses:
- Non as it relates MDSS
- Due to Location of D12 Weather does not have much impact.
- We deployed the Pikalert MDSS for two years and have recently taken a different approach to gather the departments needs and develop an RFP for a common platform for all telematics in the department including future MDSS
- Currently investigating use of decision support tools
- Influences decisions on road closures
- Decision support tools are used on a limited basis

Q20. Please specify what activities are supported by decision support tools for winter maintenance (e.g., maintenance scheduling, plow routing, material application) (If none respond "NA").

Related PM: PM#14. Number of agencies adopting MDSS technologies and methods

Table 52. Survey question 20 and associated responses

Open-Ended Answers*
AVL
Using FleetNav for vehicle tracking during winter weather operations.
Fog detection and warning
Maintenance operations
Maintenance resourcing
Maintenance scheduling (mentioned 4 times)
Application rates (mentioned 3 times)
Material application (mentioned 4 times)
Deicer and anti-icing application
Material management/ordering (mentioned 2 times)
Materials and timing
Treatment type and timing
Used to determine routes, suggested amount of application, predicted shift start/end times for enhancements when needed, tracking of material needs and anticipated usage / Staffing need, plowing and material application
Scheduling crews (mentioned 2 times)
Assuming a decision support tool includes weather forecasting, it helps up plan shifts and storm patrols
Patrols
Project underway to implement Pikalert system which includes features for recommending winter maintenance actions.
RWIS monitoring
Plowing
When to go out to plow and apply chemicals.
We assume "decision support tools" means our weather program in its entirety. We support maintenance with written weather forecasts, seasonal weather forecasts, phone support, RWIS data and alerts, snow and ice performance metrics.
Weather forecast and treatment recommendations for WMTs, Maintenance garage monitoring for before, during and after weather events.
N/A (mentioned 3 times)
None

Table 52. Survey question 20 and associated responses (continuation)

Open-Ended Answers*
We use items such as the RWIS and our AVL along with weather forecasts for "tools", but don't have a MDSS or the like.
No longer being applied. Pending future RFP

*Responses with multiple replies were broken out by topic.

- No. of respondents who answered question: 27
- No. of respondents who skipped question: 14

Q21. Please specify what activities are supported by decision support tools for non-winter maintenance (e.g., maintenance scheduling, construction coordination) (If none respond "NA").

Related PM: PM#14. Number of agencies adopting MDSS technologies and methods

Table 53. Survey question 21 and associated responses

Open-Ended Answers*
Weed spraying
Various applications such as herbicide application, etc.
Assuming a decision support tool includes weather forecasting, it helps with paving and herbicide applications
Pesticide application timing
Concrete Pour
Concrete buckling forecasts
Spraying (mentioned 2 times)
Line marking, chip seals
Lane striping forecasts.
Striping
Pavement marking
Paving operations
Chip seals
Construction projects
Construction forecasts
Road work coordination
Maintenance activities - fire danger warnings
Fire weather
Wildfire forecasts (mowing operations)
Debris flow support
Flood response
Flooding alerts
Maintenance scheduling (limited)
We use our 511 site to provide information on road construction with limited for maintenance projects. Just begun to use an app to provide maintenance activities that might have an impact on the traveling public. Still working to improve the functionality.
Weather forecast Maintenance garage monitoring for before, during and after weather events, planning for spring, summer, fall roadside maintenance activities (i.e., herbicide spraying, mowing, etc.
Unknown
N/A

Table 53. Survey question 21 and associated responses (continuation)

Open-Ended Answers*
None (mentioned 10 times)
No longer being applied. Pending future RFP

*Responses with multiple replies were broken out by topic.

- No. of respondents who answered question: 26
- No. of respondents who skipped question: 15

Q22. Please specify what activities are supported by decision support tools for traffic control and management (e.g., speed limit determination, signal timing plans, ramp metering rates) (If none respond "NA").

Related PM: PM#14. Number of agencies adopting MDSS technologies and methods

Table 54. Survey question 22 and associated responses

Open-Ended Answers*
Assuming decision support tools includes collecting traffic data, it contributes to contract development and lane closure limitations, signal timing, and other construction related maintenance of traffic restrictions.
Ramp Meter (mentioned 2 times)
Opening up shoulders for high flow times of the day and reducing speeds
Winter road closures
Pre-storm messaging
Standing water VMS automation
RWIS Monitoring
Travel time monitoring
Truck restrictions on some bridges based on forecast max. gust winds Truck restrictions (Soft Bans) based on predicted snow fall forecasts
Truck rollover road weather automation
Road weather signal timing plans
Signal timing
Road weather variable speed limit automation
Speed Limit reduction during winter weather
Speed Limit Determination
Variable speed limit systems include automated speed limit determination based on weather variables.
Variable speed limits (mentioned 2 times)
N/A (mentioned 11 times)
Not sure/Unknown (mentioned 2 times)
No longer being applied. Pending future RFP

*Responses with multiple replies were broken out by topic.

- No. of respondents who answered question: 26
- No. of respondents who skipped question: 15

Q23. Describe the level of deployment in your agency of the following weather-responsive traffic control strategies.

Related PM: PM#20. Diversity of traffic control strategies used by agencies during weather events

Table 55. Survey question 23 and associated responses

Weather Responsive Traffic Control Strategies	Deployed Statewide (or in all applicable locations)		Limited or Partial Deployment		Not Yet Deployed		Not Sure/ Unknown		Total
	No.	%	No.	%	No.	%	No.	%	
Adjust ramp meters	2	5%	4	10%	28	72%	5	13%	39
Adjust traffic signal timing	3	8%	9	23%	24	62%	3	8%	39
Employ variable speed limits to manage vehicle speeds based on real-time road weather conditions	4	10%	14	35%	20	50%	2	5%	40
Deploy ITS to determine the need to implement temporary restrictions on vehicles	4	10%	10	25%	18	45%	8	20%	40
Deploy ITS to manage traffic diversions in response to road closures	11	28%	14	36%	10	26%	4	10%	39
Employ traffic incident management practices (e.g., quick clearance policies during inclement weather, staged freeway response vehicles, coordinated evacuations during hurricanes or flooding events)	20	50%	15	38%	4	10%	1	3%	40
Other (please specify)	0	0%	0	0%	0	0%	0	0%	0

- No. of respondents who answered question: 40
- No. of respondents who skipped question: 1

Q24. Describe the level of deployment in your agency of the following treatment and operations strategies.

Related PM: PM#20. Diversity of traffic control strategies used by agencies during weather events

Table 56. Survey question 24 and associated responses

Treatment and Operations Strategies	Deployed Statewide (or in all applicable locations)		Limited or Partial Deployment		Not Yet Deployed		Not Sure/ Unknown		Total
	No.	%	No.	%	No.	%	No.	%	
Real-time use of data and/or decision support algorithms to determine strategies for pre-treating roads for snow and ice	17	43%	12	30%	11	28%	0	0%	40
Real-time use of data and/or decision support algorithms to determine strategies for routes of snowplows or chemical application	14	36%	7	18%	17	44%	1	3%	39
Real-time use of data and/or decision support algorithms to determine strategies for chemical application rates	12	30%	12	30%	14	35%	2	5%	40
Flood barrier systems (inflatable barriers, sandbag systems)	3	8%	6	15%	27	69%	3	8%	39
Unmanned aerial systems (i.e., drones) to support data collection to assist road weather management applications	4	10%	7	18%	25	63%	4	10%	40
Other (please specify)	0	0%	0	0%	0	0%	0	0%	0

- No. of respondents who answered question: 40
- No. of respondents who skipped question: 1

Q25. Does your agency use decision support tools to help automate road weather operations and maintenance decision-making? If so, for what event types? (*check all that apply*)

Related PM: PM#14. Number of agencies adopting MDSS technologies and methods

Table 57. Survey question 25 and associated responses

Answer Options	No.	Percentage
No—do not need decision support tools for road weather management	7	18%
No—there is a need, but there are currently no plans to implement new tools	5	13%
No—no tools are currently used; however, new tools are being planned or implemented soon	6	15%
Yes—use for winter weather events, but not Statewide	6	15%
Yes—use for winter weather events Statewide	12	31%
Yes—use for flooding events	1	3%
Yes—use for wildfire events and burn scar management	1	3%
Yes—use for storm events (e.g., rain, thunder)	1	3%
Yes—use for high wind events	6	15%
Yes—use for low visibility events (e.g., dust, fog)	4	10%
Not Sure/Unknown	2	5%
Other (please specify)	5	13%

- No. of respondents who answered question: 39
- No. of respondents who skipped question: 2

Other (please specify) responses:
- IMO was installed in part in December 2020 just started learning the applications
- If you are only considering MDSS, then it's "No"
- Originally implemented the Pikalert system and have recently taken a step back to gather the departments needs and develop an RFP for a common platform including the needs of an MDSS
- Road weather decision are made manually using DOT Weather Operations forecasts and RWIS data.
- We don't have automated, but have data (RWIS, forecasts) to help with decision making at the supervisor level.

Q26. Does your agency actively collaborate with other agencies (e.g., as part of pooled funds, cooperative agreements, or individual projects) that research road weather management topics and are not Federally sponsored or funded?

Related PM: PM#6. Number of agencies researching the role of connected and automated vehicles in road weather management

Table 58. Survey question 26 and associated responses

Answer Options	No.	Percentage
Yes	24	60%
No	8	20%
Not Sure/Unknown	8	20%

- No. of respondents who answered question: 40
- No. of respondents who skipped question: 1

Q27. Please specify any information you are comfortable sharing regarding the collaboration with other agencies (e.g., as part of pooled funds, cooperative agreements, or individual projects) that research road weather management topics and are not Federally sponsored or funded.

Related PM: PM#6. Number of agencies researching the role of connected and automated vehicles in road weather management

Table 59. Survey question 27 and associated responses

Open-Ended Answers
AASHTO, NCHRP, Western States Rural Transportation Consortium
Aurora pooled fund, Enterprise pooled fund
Belong to: Clear Roads MDSS Aurora No Boundaries Northwest Passage
Participates in the Clear Roads Pooled Fund.
We belong to the Clear Roads Pooled Fund and the Aurora Pooled Fund.
Participates in the clear roads pooled fund and the Northwest passage pooled fund.
TMC Poll Fund Studies
MDSS Pooled Fund
MDSS Pooled Fund Study, North/West Passage Pooled Fund Study, Clear Roads Pooled Fund Study
All of our programs have had some federal funding sources
Partnership with State Mesonet for weather risk assessment dashboard.
Regular coordination with other State agency partners on winter activities, hurricane preparedness/contra flow exercises
Currently involved in a Mini RWIS pilot project

- No. of respondents who answered question: 13
- No. of respondents who skipped question: 28

Q28. Was your agency's decision to initiate any road weather management research and/or collaboration efforts influenced by FHWA's Road Weather Management Program?

Related PM: PM#6. Number of agencies researching the role of connected and automated vehicles in road weather management

Table 60. Survey question 28 and associated responses

Answer Options	No.	Percentage
Yes	28	70%
No	2	5%
Not Sure/Unknown	10	25%

- No. of respondents who answered question: 40
- No. of respondents who skipped question: 1

Q29. Please specify the nature of the road weather management research and/or collaboration efforts influenced by FHWA's Road Weather Management Program.

Related PM: PM#6. Number of agencies researching the role of connected and automated vehicles in road weather management

Table 61. Survey question 29 and associated responses

Open-Ended Answers*
I was the SME for IMO 1-3
EDC-4
Recipient of EDC AID Funding for Weather Savvy Roads.
IMO
EDC-5
WRMS
Exploring DSRC technologies for connecting Plow Trucks, private vehicles and Mesonet stations.
IMO deployments, RWIS deployments, CCTV monitoring systems, research, partnerships with university.
MARWIS
MDSS (mentioned 4 times)
Pikalert MDSS was supported through RWM program
The MDSS Pooled Fund Study was initiated in response to FHWA RWMP initiatives in early 2000s.
Clear Roads
Aurora (all funded via FHWA/SPR dollars)
Participated in the effort with FHWA and the I-95 Corridor Coalition to create standardized messaging for our message boards.
Pathfinder Program (mentioned 5 times)
We have created documentation for citizen reporting and Pathfinder. Pathfinder is in the early stages of deployment for us now.
Plans for Installation
Road Weather Management National Meetings
The need for a winter event impact factor was discussed with the members of the program.
The team I am part of has relied heavily on guidance from the Road Weather Management Program. I think we have a pretty advanced system and in many ways, this was built based on lessons learned from and guidance from the RWMP.
To be more proactive in alerting the travelling public using all tools we have.
Working with FHWA RWMP and our local FHWA office, we have been working to implement more technology to provide information to our staff on weather management.
Great source of best practices information to inform agency efforts.

*Responses with multiple replies were broken out by topic.

- No. of respondents who answered question: 24
- No. of respondents who skipped question: 17

Q30. What types of analysis tools does your agency use to either support real-time operations or non-real-time planning of road weather management activities? (check all that apply)

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

Table 62. Survey question 30 and associated responses

Answer Options	No.	Percentage
None	4	10%
Real-time tools to support roadway maintenance during road weather events	29	74%
Real-time tools to support traffic control or management during road events	15	28%
Non-real-time tools to predict impacts of road weather management strategies (e.g., mesoscopic simulation models, microscopic simulation models) as used in planning or developing operational procedures	6	15%
Non-real-time tools to conduct post-event analysis of road weather management response actions	14	36%
Not Sure/Unknown	3	8%

- No. of respondents who answered question: 39
- No. of respondents who skipped question: 2

Q31. Has your agency (in particular road weather management-related staff) participated in extreme weather, transportation resilience, and/or climate adaptation practices/reviews? (check all that apply)

Related PM: PM#22. Number of agencies conducting vulnerability/risk assessment or developing/implementing resiliency plans for their RWM infrastructure and processes to respond to extreme weather

Table 63. Survey question 31 and associated responses

Answer Options	No.	Percentage
Developed/implemented resiliency plans for road weather management infrastructure.	7	18%
Conducted a vulnerability/risk assessment for road weather management infrastructure	10	26%
Participated in State DOT Climate Change Adaptation planning activities	8	21%
Has not participated in the development of adaptation practices	8	21%
Developed/implemented process for responding to extreme weather	12	31%
Has not participated in the development of an extreme weather response process	8	21%
Not Sure/Unknown	13	33%

- No. of respondents who answered question: 39
- No. of respondents who skipped question: 2

Q32. Has your agency (in particular road weather management-related staff) participated in any self-assessment or capability maturity exercises to examine and improve road weather management practices? (check all that apply)

Related PM: PM#16. Number of agencies that have participated in or conducted RWM capability maturity assessment exercises

Table 64. Survey question 32 and associated responses

Answer Options	No.	Percentage
Participated in FHWA Road Weather Management Capability Maturity Framework (CMF) workshop.	14	36%
Conducted self-assessment using the FHWA Road Weather Management CMF online tool	7	18%
Conducted self-assessment using other capability maturity tool(s)	2	5%
Developed/implemented new practices, processes, or technologies that were identified in a capability maturity exercise in prior years	8	21%
Have not participated in any road weather management capability maturity exercise	8	23%
Not Sure/Unknown	13	33%

- No. of respondents who answered question: 39
- No. of respondents who skipped question: 2

Q33. If not the FHWA Road Weather Management CMF online tool please specify what capability maturity tool(s) your agency used to conduct a self-assessment.

Related PM: PM#16. Number of agencies that have participated in or conducted RWM capability maturity assessment exercises

Table 65. Survey question 33 and associated responses

Open-Ended Answers
It has been quite some time. However, believe our agency has participated in a RWM CMF years ago.
Pooled Fund is currently developing a RWIS Life Cycle Cost Analysis Tool
Not sure
N/A (mentioned 5 times)
None

- No. of respondents who answered question: 9
- No. of respondents who skipped question: 32

Appendix B. Assessment Findings by Performance Measure

OBJECTIVE 1. STAKEHOLDER ENGAGEMENT

Table 66. Summary of objective 1 performance measures

Performance Measure	Submeasure	Observations	Rating	Likely Needs for Program
PM 1. Number of agencies participating in and benefiting from RWM stakeholder meetings and workshops OVERALL RATING— STRONG PERFORMANCE	Participation Records	There is significant event participation that continues to increase year-over-year. This is indicative of a continued interest in RWMP programming and topics by State agencies and other industry participants. These findings indicate that the program continues to evolve to meet the needs of its partners and provide relevant programming to help enhance RWM efforts across the country.	👍	Continue developing event programming based on stakeholder needs and pushing events via outreach methods such as emails, newsletters, and advertisements at industry events. Consider using virtual event tools when beneficial to participation.
PM 2. Number of agencies and participants in RWM webinars led by the RWMP OVERALL RATING— STRONG PERFORMANCE	Participation Records	The level of participation for WRMS webinars and the 2019 and 2020 regional roundtables indicates a continued interest in RWMP topical offerings and an interest in continued engagement among the stakeholder community with FHWA acting as moderator.	👍	Continue to work with agencies to identify topics of interest and conduct webinars and other events on a regular basis to promote education and best practices as well as peer-to-peer information sharing.
PM 3. Number of meetings, site visits, or venues where RWM presentations briefings were made OVERALL RATING— STRONG PERFORMANCE	Participation Records	There is consistently strong participation across the industry and by State agencies at public activities in which the RWMP representatives are either attending, presenting, or moderating.	👍	Continue to take the pulse of the industry and promote RWM initiatives at national and international meetings, workshops, and conferences by making presentations and working with organizational champions and points of contact.

OBJECTIVE 2. RESEARCH AND DEVELOPMENT

Table 67. Summary of objective 2 performance measures

Performance Measure	Submeasure	Observations	Rating	Likely Needs for Program
PM 4. Number of agencies participating in road weather R&D projects OVERALL RATING— STRONG PERFORMANCE	Participation Records	There is continued interest and rising participation levels for most of the R&D projects examined (Pathfinder, WRMS, WxDE). For IMO, leveling off of participation may be attributed to mobile observations becoming mainstream in agency operations	👍	Continue to work with agencies to push projects (which are ready) into the mainstream.
PM 5. Number of agencies researching the role of connected and automated vehicles in road weather management. OVERALL RATING— MODERATE PERFORMANCE	Use of applications and tools	The majority of States surveyed are considering the use of apps/tools to gather and use mobile road weather data from infrastructure and/or CAVs but have yet to develop them. While a third of States surveyed have developed them, 15 percent of States are unsure of the status of any such tool.	👍	Given the newness of this focus area, it is encouraging to see so much interest. The RWMP should nurture this interest through demonstrations, peer exchanges, and site visits in which agencies can learn from one another - sharing ideas and lessons learned. Additionally, materials such as case studies and fact sheets should be developed to aid agencies in understanding not only how to implement but also the related benefits and costs to help "make the case" to leadership and gain the necessary buy-in

Table 67. Summary of objective 2 performance measures (continuation)

Performance Measure	Submeasure	Observations	Rating	Likely Needs for Program
PM 5. Number of agencies researching the role of connected and automated vehicles in road weather management OVERALL RATING—MODERATE PERFORMANCE	Strategic Planning Documents	Approximately half of all responses indicate V2I connectivity is included in planning documents while the remaining half either do not have any documentation or are unsure of the status. One-third of responses noted the inclusion of automated driving capabilities in documentation, one third noted no documentation, and the remaining one third are unsure of the status.	👊	Given the newness of this focus area, it is important for the RWMP to provide learning opportunities and ways for early adopters to work with interested parties to better understand how connectivity and automated driving capabilities can support RWM.
	Organizational participation	The majority of responses indicate agencies are interested in talking with external organizations about the use of connected vehicles, automated driving capabilities, or both to support RWM.	👍	In support of these external discussions, the RWMP should continue to participate in or facilitate sessions at industry events. This will enable the RWMP to not only take the pulse of industry development but also to help guide agencies and provide technical assistance.
	Agency research, demonstrations, tests, deployments	Nearly half of respondents indicated they are conducting activities that support the use of infrastructure to broadcast information to support in-vehicle RWM applications or messaging. About a quarter said they are not doing anything, and the rest are unsure.	👊	The RWMP should continue to provide support (i.e., technical assistance, grant opportunities, informational materials, etc.) to agencies interested in pursuing CAV related efforts to enhance RWM practices. This may also include cross-agency efforts with other groups such as the USDOT Intelligent Transportation Systems Joint Program Office**.**

Table 67. Summary of objective 2 performance measures (continuation)

Performance Measure	Submeasure	Observations	Rating	Likely Needs for Program
PM 6. Number of non-USDOT R&D road weather projects that State DOTs are engaged in OVERALL RATING—STRONG PERFORMANCE	Participation in non-Federally sponsored research	The majority of States responded that they are collaborating with other groups in non-USDOT sponsored research with a multitude of PFS and other consortium opportunities listed.	👍	Continue to provide opportunities for the road weather industry to come together (e.g., national stakeholder meetings) to enable open discussions, networking, and learning opportunities so States can continue to identify different opportunities for collaborative partnerships and related programming.
	Influence of the RWMP	The majority of States participating in non-sponsored research noted that the RWMP influenced their decision to do so.	👍	Continue to promote research and to provide opportunities for States to participate in events in which they can learn about different research projects in the road weather community.

OBJECTIVE 3. DEPLOYMENT

Table 68. Summary of objective 3 performance measures

Performance Measure	Submeasure	Observations	Rating	Likely Needs for Program
PM 7. Number of State DOTs participating in WxDE program OVERALL RATING—STRONG PERFORMANCE	Participation Records	Participation in the WxDE program has greatly increased since 2019.	👍	Continue outreach activities to share benefits of contributing to the WxDE in order to encourage increased agency participation.
PM 8. Number of State DOTs that subscribe to road weather products and services OVERALL RATING—STRONG PERFORMANCE	Subscription and use of "traditional" weather and road weather products and services	Agency use of most traditional products remains relatively stable. Most agencies continue subscribing to NWS products, using fixed agency sensors, and leveraging agency field personnel and private weather service providers.	👍	The RWMP may consider identifying and individually reaching out to the relatively few State DOTs that do not use these "traditional" products and services to understand their current practices and potentially encourage a workshop to promote use of these offerings.
	Subscription and use of newer, "innovative" weather and road weather products and services	Agency use of newer and most innovative products remains relatively stable, however there is potential for more agencies to leverage these available products and services, such as mobile agency sensors, crowdsourcing, and social media.	👍	The RWMP should continue developing case studies and conducting outreach activities, such as webinars, workshops, peer exchanges, and stakeholder meeting sessions to promote the benefits of using these innovative products and strategies.

Table 68. Summary of objective 3 performance measures (continuation)

Performance Measure	Submeasure	Observations	Rating	Likely Needs for Program
PM 9. Number of State DOTs collecting mobile observations of road weather data from vehicle fleets OVERALL RATING—STRONG PERFORMANCE	Percentage of agencies	The percentage of agencies that collect real-time fleet vehicle data continues to increase.	👍	The RWMP may conduct outreach activities to agencies that are not collecting and using mobile observations in order to understand whether there is a need for further outreach to promote use, depending on the potential benefits of mobile observations to those agencies.
	Percentage of fleet collecting various types of data	The percentage of agency fleets collecting various types of mobile observations generally continues to increase from previous years, but there remains room for growth for all types of data as relatively few agencies collect data for all fleet vehicles.	👍	The RWMP should continue developing case studies and conducting outreach activities, such as webinars, workshops, peer exchanges, and stakeholder meeting sessions to promote the benefits of expanding the use of mobile observation data, including new and innovative ways to leverage the data. Road images and video is the least collected (and most recently added emerging technology. The RWMP may consider a best practices webinar to allow those agencies that have deployed this to share their experiences with others.

Table 68. Summary of objective 3 performance measures (continuation)

Performance Measure	Submeasure	Observations	Rating	Likely Needs for Program
PM 10. Number of State DOTs reporting use and diversity in use of Environmental Sensor Stations (ESS) in operations and maintenance activities OVERALL RATING—STRONG PERFORMANCE	Number of Agency ESS	The number of ESS deployed continues to increase, suggesting that agencies are aware of the value and continue to support the use of ESS.	👍	The RWMP may consider individually reaching out to agencies that have few or no ESS in order to provide support, as needed (e.g., demonstrating benefits, facilitating a peer exchange) or to understand why ESS are not deployed (e.g., is there not a need for ESS? Are needs met through other devices?).
	Agency Usage of ESS	Agency use of ESS remains relatively stable for various purposes. There may be potential for more agencies to leverage ESS in additional ways other than their current practices. Segment level forecasts may become more critical as automated vehicle use increases and operational design domains are established regarding weather and driving conditions. The use of ESS may for segment level forecasts may become more critical.	👍	The RWMP may wish to further examine how individual agencies are using ESS in order to determine whether case studies or outreach activities like webinars or sessions at the annual road weather stakeholder meeting are needed to encourage greater agency use of deployed ESS. Consider cross-cutting events with ADS integration research at FHWA to assess the need for and role of segment level forecasts to support the ADS digital infrastructure.

Table 68. Summary of objective 3 performance measures (continuation)

Performance Measure	Submeasure	Observations	Rating	Likely Needs for Program
PM 11. Number of/percentage of responding agencies using mobile data-based applications in road weather management OVERALL RATING— MODERATE PERFORMANCE	Agencies developing applications	Agency mobile data-based application development has decreased somewhat, although interest in applications has increased (as well as respondents who were unsure).	👎	The RWMP should consider developing case studies to highlight benefits and successful mobile data-based applications that are being used, facilitate the sharing of developed applications between agencies, and/or conduct outreach activities like workshops or peer exchanges to encourage greater agency use of these applications.
PM 12 Number of States disseminating advisory weather and road weather information to travelers OVERALL RATING— STRONG PERFORMANCE	Traveler Information Dissemination	Generally, agencies continue to use a variety of mechanisms to disseminate road weather traveler information at consistent levels.	👍	The RWMP may wish to conduct general or targeted outreach to encourage agencies to disseminate more types of road weather information Statewide via all appropriate mechanisms (e.g., agency-hosted website and DMS).
	Safety Warning Systems	The number of agencies deploying safety warning systems for road weather conditions continues to increase.	👍	The RWMP may develop case studies to highlight benefits and successful safety warning systems that are being used and conduct outreach activities like workshops or peer exchanges to encourage greater agency use of these systems.

Table 68. Summary of objective 3 performance measures (continuation)

Performance Measure	Submeasure	Observations	Rating	Likely Needs for Program
PM 13. Number of agencies that coordinate with their local forecast offices for road weather management and operations OVERALL RATING—STRONG PERFORMANCE	Agency Coordination with Local Forecast Office	A significant percentage of agencies continue to coordinate with the NWS for both winter and non-winter weather events.	👍	The RWMP should continue to encourage agencies to coordinate with the NWS. This may include continued promotion of the Pathfinder initiative as a mechanism to increase agency coordination with NWS, particularly to States that have not yet officially implemented it in order to formalize the agency processes and interactions with the NWS
	Pathfinder Initiative	A significant percentage of agencies coordinate with the NWS for messaging for both winter and non-winter weather events, and more than half attribute this to FHWA efforts.	👍	The RWMP should continue to promote the Pathfinder initiative to States that have not yet implemented it, and also promote expansion of Pathfinder practices to additional types of events and Statewide.
PM 14. Number of agencies adopting decision support technologies and methods OVERALL RATING—MODERATE PERFORMANCE	Agency Use of Decision Support Systems	Agency use of decision support systems remains similar to the 2019 update.	👊	The RWMP may develop case studies to highlight benefits and successful decision support systems that are being used and conduct outreach activities like workshops or peer exchanges to encourage greater agency use of these systems.

OBJECTIVE 4. KNOWLEDGE AND TECHNOLOGY TRANSFER

Table 69. Summary of objective 4 performance measures

Performance Measure	Submeasure	Observations	Rating	Likely Needs for Program
PM 15. Numbers of agencies and attendees who have taken any of the sponsored RWMP training courses and workshops OVERALL RATING— NEEDS IMPROVEMENT	Training records	During this assessment period no external RWMP-sponsored training occurred because the training was outdated and was removed from the website.	👎	When the revised NHI course is completed, the RWMP should conduct broad outreach (such as through GovDelivery and industry events) to raise awareness of the updated web-based training and how stakeholders can sign up.
PM 16. Number of agencies that conduct periodic assessments of RWM capabilities or performance OVERALL RATING— STRONG PERFORMANCE	CMF Assessments across State Agencies	Agencies continue to be interested in conducting assessments of their programs using the RWM CMF.	👍	Updates to the RWM CMF are fairly new and should continue to be promoted through outreach activities. The new modular, flexible CMF will be useful not only to agencies that have not yet conducted an assessment but also to those that have previously conducted an assessment and are ready to see where they stand after changes in the Framework and their own agencies.

Table 69. Summary of objective 4 performance measures (continuation)

Performance Measure	Submeasure	Observations	Rating	Likely Needs for Program
PM 17. Number of RWM meetings and webinars that include topics specific to each of the program focus areas and trends OVERALL RATING—STRONG PERFORMANCE	Expanded Data Collection and Use	The topic of expanded data collection and use is covered across the majority of events.	👍	Continue to plan for and conduct events as has been done in the past.
	Collaboration	There is clear and extensive coverage of collaboration among RWMP activities.	👍	Continue to plan for and conduct events as has been done in the past.
	Vehicle Automation	There is a lack of focus on vehicle automation among RWM events. Given the newness of the topic and its lack of broad application, this is to be expected.	👎	Work with State agencies and research institutions to identify pilots and other use cases of innovation with respect to vehicle automation to enable more discussion and understanding of the topic among the RWM stakeholders
	Automated Decisionmaking	Automated decision making is often discussed but does not appear to be a topic of priority among many events.	✊	Work with State agencies and research institutions to identify pilots and other use cases of innovation with respect to automated decision making to enable more discussion and understanding of the topic among the RWM stakeholders
	Focus on Severe Weather	There is clear and extensive coverage of severe weather across the RWMP activities.	👍	Continue to plan for and conduct events as has been done in the past.

OBJECTIVE 5. INNOVATION, RESILIENCE, AND SUSTAINABILITY

Table 70. Summary of objective 5 performance measures

Performance Measure	Submeasure	Observations	Rating	Likely Needs for Program
PM 18. Reduction in number and types of fatalities and crashes attributed to adverse weather nationally OVERALL RATING—MODERATE PERFORMANCE	Impacts on Fatal Crashes	There is no data, for either crash rate per billion VMT or per licensed driver, that suggests a significant change in fatal crashes related to inclement weather. In 2019 fatalities in crashes per thousand licensed drivers and in crashes per billion VMT, declined. Earlier years also showed few fatal crashes, therefore it is unknown if this represents a downward trend or the cycle seen through past years.	✊	The RWMP should consider continuing all activities to support safety during inclement weather and road weather events. There are anecdotal reports of increased safety, and it is encouraging that fatal crashes are not increasing.
PM 19. Reduction in number of tons of salt or chemical usage in the US normalized by winter severity index OVERALL RATING—STRONG PERFORMANCE	National Salt Usage for Roadway Maintenance	Salt usage remains relatively constant at the national level, with mild winters causing dips in usage, suggesting that strategies for reducing salt use are not yet widespread enough to have an overall impact on use.	✊	The RWMP should consider identifying State DOTs willing to volunteer to offer their salt consumption statistics to correlate States' implementation of new snow and ice management approaches with reductions in salt usage.
	Case Studies	There are examples of innovative and creative approaches to reducing salt usage. Over the coming years, these agencies will better understand the impacts of these approaches.	👍	Consider outreach activities to allow agencies with salt reduction approaches to share with other State DOTs. Track salt use by agencies adopting these approaches in future performance management assessments.

Table 70. Summary of objective 5 performance measures (continuation)

Performance Measure	Submeasure	Observations	Rating	Likely Needs for Program
PM 20. Diversity of traffic control and road treatment strategies used by agencies during weather events OVERALL RATING— STRONG PERFORMANCE	Use of Real-time Data and/or Decision Support for Road Treatment Strategies	More than half of survey responders use data and/or decision support for the three road treatment strategies queried (pretreatment, chemical application rates, and routes for snowplows or chemical application). Pretreatment was used the most of the three.	👍	The RWMP should continue outreach in this regard because it has been successful. Consider discussing additional topics for determining route selection or chemical application rates in future outreach.
	Use of Innovative Traffic Management Strategies	There is a high rate of use of traffic incident management strategies, deployment of ITS to divert traffic, and use of variable speed limits during inclement weather, suggesting these strategies are well known and valued. Approximately one-third of survey responders reported using ITS to determine the need for vehicle restrictions, and there was limited use of signal timing or ramp meter adjustments, suggesting the industry could benefit from more outreach and demonstrations of benefits for these.	👍	Consider outreach activities to allow agencies that use ITS to determine vehicle restrictions to demonstrate the systems to other States. Consider working with traffic engineering groups to explore wider use of traffic management approaches to respond to weather events.
	Use of Other Innovative Tools	The rate of use of UAS by 27 percent of responders indicates that drones are quickly growing in popularity with State DOTs. The use of innovative flood barriers is less common, but this may indicate that flooding affects fewer agencies.	👍	Consider showcasing UAS use and benefits. Consider discussing if flooding is a concern to those that indicated they do not use innovative approaches to retain floodwaters.

Table 70. Summary of objective 5 performance measures (continuation)

Performance Measure	Submeasure	Observations	Rating	Likely Needs for Program
PM 21. Number of agencies reporting use of appropriate analysis tools to factors weather impacts and strategies OVERALL RATING— MODERATE PERFORMANCE	Real-time: Roadway maintenance	There is strong use of real-time tools to support road maintenance activities during weather events, suggesting State DOTs benefit from this and that the RWMP has been effective at encouraging and educating State DOTs about this critical activity.	👍	Continue this emphasis area as in the past.
	Real-time: Traffic control or management	There is moderate use of real-time tools to support traffic control or management during weather events—33 percent of responders.	✊	Consider additional outreach activities, potentially to reach the groups or individuals responsible for traffic management in the State DOTs.
	Postevent analysis	There is moderate use of tools to perform post-event analysis of weather management activities—32 percent of responders.	✊	Consider additional outreach to encourage use of tools. Consider sharing best practices and lessons learned by agencies that indicated they use postevent analysis tools.
	Prediction of impacts of RWM strategies	There is limited use of tools to predict impacts of road weather management strategies—15 percent of responders). This may suggest that these tools are less mature or that the benefits of using these tools are less known.	👎	The RWMP could seek to understand these tools and demonstrate their use.

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Table 70. Summary of objective 5 performance measures (continuation)

Performance Measure	Submeasure	Observations	Rating	Likely Needs for Program
PM 22. Number of agencies conducting vulnerability risk assessment or developing and implementing resiliency plans, for their RWM infrastructure and processes to respond to climate change and extreme weather OVERALL RATING— MODERATE PERFORMANCE	State DOT Participation in Climate Change Adaptation Planning	More than half the responders who were aware of their agency's status confirmed that they have participated in climate change adaptation planning, but this number is not a significant change over earlier years, which suggests more agencies would benefit from this planning.	👍	Consider new activities to reintroduce climate change adaptation planning to encourage agencies to participate.
	State DOT knowledge of whether they have participated in climate change adaptation planning	Approximately half of responders did not know if their agency has participated in climate change adaptation planning, and four agencies that previously responded "yes" now responded that they were not sure. This suggests that the individuals' knowledge about adaptation planning varies and that States might benefit from refresher exercises to encourage internal sharing of previous planning activities.	👎	Consider sharing best practices by State DOTs in climate change adaptive planning. Consider also compiling a list of agencies that have previously indicated they have performed adaptive planning to share with other States.
	Preparation of Extreme Weather Response Processes	Among responders aware of their agency's status, 57 percent confirmed that they have developed or implemented extreme-weather response processes. Six agencies confirmed this action that had not previously confirmed it, suggesting that agencies are probably still implementing these activities. The fact that 43 percent of responders confirmed they have not developed or implemented extreme-weather response processes suggests agencies still need encouragement and assistance in taking this step.	👍	Consider new activities reintroducing the development of extreme-weather response processes for the six agencies that indicated they have not completed this.

Table 70. Summary of objective 5 performance measures (continuation)

Performance Measure	Submeasure	Observations	Rating	Likely Needs for Program
PM 22. Number of agencies conducting vulnerability risk assessment or developing and implementing resiliency plans, for their RWM infrastructure and processes to respond to climate change and extreme weather OVERALL RATING— MODERATE PERFORMANCE	State DOT Knowledge of Whether it has Participated in Extreme Weather Process Development	Approximately half of responders did not know if their agency has developed or implemented extreme-weather response processes. This suggests that respondents' knowledge about activities focused on extreme weather varies greatly.	👎	Consider sharing by State DOTs of best practices in extreme weather response process development and implementation. Also consider compiling a list of agencies that have previously indicated they have developed and implemented these processes to share with other States.
	Vulnerability Risk Assessment Understanding for RWM Infrastructure	Less than 30 percent of responders indicated they have conducted vulnerability risk assessment for RWM infrastructure. This suggests the risks and vulnerabilities are not well understood. This response has not increased over 2019.	👎	Consider new activities to encourage vulnerability and risk assessment of RWM infrastructure, perhaps through sessions in annual RWM meetings or special webinars
	Resilience Planning for RWM Infrastructure	Less than 20 percent of responders indicated they have developed resilience plans for RWM infrastructure. This is a decrease from 2019. This suggests that few State DOTs have resilience plans for RWM infrastructure; it also implies that different levels of vulnerability are possible.	👎	Consider new activities to encourage resilience planning for RWM infrastructure, perhaps through sessions in annual RWM meetings or through special webinars.