Resources, Practices and Needs for Weather Forecasting to Facilitate Winter Road Maintenance

Synthesis Report

CLEAR ROADS

research for winter highway maintenance

CTC & Associates LLC

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16. Abstract A transportation agency's ability to deliver effective winter road maintenance combines three essentials: a professional, knowledgeable staff, including trained snowplow operators; a fleet of high-quality, well-maintained equipment and appropriate supplies; and, perhaps most important and most difficult to consistently acquire, accurate and timely weather information. Sources of weather information for transportation agencies are many and varied. This synthesis project sought to determine the best practices agencies use to acquire accurate and timely weather information to strategize and deploy equipment for winter road maintenance operations. The project also examined the practices used to convey information about forecasts and road weather conditions between agency offices and operators in the field. Two surveys directed to winter road maintenance practitioners at Clear Roads member agencies gathered information from central office staff and field personnel. Results of a literature search supplement survey findings.			
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Sources of weather information for transportation agencies are many and varied. They range from local weather broadcasts and numerous national online weather data sources, such as websites and apps, to contract forecasting services and on-staff meteorologists. Many agencies also gather data from a local road weather information system (RWIS) and mobile advanced road weather information system (MARWIS) sensors on agency vehicles.

This synthesis project sought to determine the best practices agencies use to acquire accurate and timely weather information to strategize and deploy equipment for winter road maintenance operations. The project also examined the practices used to convey information about forecasts and road weather conditions between agency offices and operators in the field.

Two surveys directed to winter maintenance practitioners at Clear Roads member state departments of transportation (DOTs) gathered information about their resources, practices and needs regarding the acquisition and use of accurate and timely weather information. One survey targeted staff members in agency central offices. The second survey was distributed to winter road maintenance field personnel selected by central office staff. Survey results are presented separately in the report, beginning with the central office survey on page 7; findings from the field personnel survey begin on page 27. Findings from both surveys are summarized together below.

The results of a literature search, which begin on page 42, supplement survey findings.

Survey of Practice

Two online surveys of the 36 Clear Roads member agencies garnered responses from 22 states (central office survey) and 62 respondents from 17 states (field personnel survey). While survey findings are presented separately in the report, this summary of survey findings brings together responses from the two respondent groups to allow for comparison of respondents' feedback in four topic areas:

- Information Sources
- Managing Forecasts
- Managing Maintenance Actions
- Managing Weather Information

A fifth topic area—Working with Meteorologists and Partners—was addressed by only central office respondents.

Information Sources

Sources for Weather Forecasts

Respondents identified the sources of weather forecasts and conditions used by their agencies' maintenance supervisors when deciding when and where to mobilize crews for plowing, deicing, anti-icing and other winter maintenance activities.

Both groups of respondents acquire weather information from four main sources:

- National Weather Service
- Paid weather forecasting services
- Local TV news
- Weather websites or apps

Four of the 22 central office respondents reported retaining an in-house meteorologist (Rhode Island, Utah, Washington and Wisconsin), while 16 of the 62 field personnel respondents indicated their agencies had an in-house meteorologist. Both central office and field personnel respondents reported limited use of federal weather observing data systems such as Automated Surface Observing Systems (ASOS) and Automated Weather Observing Systems (AWOS), both a joint effort between the Federal Aviation Administration (FAA) and the National Weather Service (NWS). Central office respondents offered detailed information about the paid weather forecasting services and weather websites and apps their agencies use to gather weather data.

Sources for Road Weather Conditions
Most central office staff rely heavily on RWIS and traffic video from snowplows to obtain information about road weather conditions, with many of these respondents also reporting the use of data from DOT vehicle mobile sensors and reports from plow drivers. Field personnel also reported heavy reliance on reports from plow drivers, as well as video from snowplows, DOT vehicle mobile sensors and their own visual assessment. Field personnel are least likely to use public reports as a source for weather information.

Working with Meteorologists and Partners

Only central office respondents addressed questions related to an in-house meteorologist.

Agencies Employing an In-House Meteorologist
Respondents from four states—Rhode Island, Utah, Washington and Wisconsin—employ an in-house meteorologist. Rhode Island and Utah DOTs employ a full-time staff person; Washington State and Wisconsin DOTs employ a contractor or consultant. Wisconsin DOT has had a consultant meteorologist for 25 years; Washington State DOT has retained one for more than 15 years. Rhode Island DOT's meteorologist has the shortest tenure, at four years. Only the Washington and Wisconsin respondents provided annual costs associated with their consultant meteorologists ($120,000 and $130,000, respectively).

Respondents reported greater confidence in forecasts, in-person access and the meteorologist's participation as liaison to emergency management or traffic management as the primary benefits associated with retaining an in-house meteorologist.

Agencies Not Employing an In-House Meteorologist
Agencies not employing an in-house meteorologist cited other weather information sources and an uncertainty with regard to the benefits of retaining a meteorologist as the reasons for seeking weather information from other sources.

Some respondents provided additional comments about their agency's decision not to retain an in-house meteorologist, including a strong relationship with National Oceanic and Atmospheric Administration (NOAA) (Idaho), a contract with DTN that provides sufficient information (Minnesota),

and ample outside weather sources such as interns from nearby universities (Pennsylvania). Indiana, West Virginia and Wyoming respondents indicated that their agencies are considering employing an in-house meteorologist in the future.

Engaging with Meteorologists

Both respondent groups engaged with meteorologists to some extent even if their agencies did not have an in-house meteorologist. In addition to retaining a meteorologist in-house, agencies might engage with a meteorologist from NWS or a paid weather forecast service, or one affiliated with a partnership or coalition.

Central office respondents most frequently engage with a paid weather forecast service (slightly more often than for about half of storm events). These respondents reported the least amount of engagement with meteorologists associated with a partnership or coalition. Field personnel respondents are also most likely to engage with a meteorologist from a paid weather service and least likely to interact with an in-house meteorologist. For field personnel, all of the meteorologist types are contacted in connection with fewer than half of storm events.

Partnerships to Share Weather Condition and Forecasting Information

Some responding agencies participate in a partnership or coalition with other agencies or organizations to share information about weather conditions and forecasts. Respondents highlighted engagement with emergency management, Federal Highway Administration's (FHWA's) Pathfinder project, NWS and a pooled fund study (TPF-5(347) Development of Maintenance Decision Support System).

Managing Forecasts

Assessing Weather Forecasts and Road Condition Information

Respondents were asked to rate their level of confidence in the weather forecasts and condition information their agencies receive from a variety of information sources. When providing these ratings, respondents considered past experiences as well as current sources of weather information, rating each information source using the following rating scale:

- 1 = Not at all confident
- 2 = Slightly confident
- 3 = Moderately confident
- 4 = Very confident
- 5 = Extremely confident

The four agencies with in-house meteorologists reported a high level of confidence in the weather forecasts provided by those meteorologists. For agencies not retaining an in-house meteorologist, paid weather forecasting services, and forecasts from NWS and FAA's ASOS and AWOS, garnered the highest ratings from the central office respondents using these services. Some central office respondents also commented on other weather information resources they had tried but did not find useful and information resources they would like to try.

For field personnel, forecasts from NWS and an in-house meteorologist garnered the highest ratings. Respondents reported the least confidence in forecasts from local TV news. The Utah DOT respondent noted that "[r]oad weather forecasting is the only service that is valuable. Other forecast information

does not provide the information needed to make good decisions. There is a huge advantage to having forecasters inside the organization."

Managing Forecast Uncertainty

Respondents described how maintenance supervisors manage uncertainty about forecast accuracy by selecting from among several practices. Eighty-five percent of central office respondents compare multiple forecasts, while almost two-thirds contact NWS or a paid forecast service. Central office respondents were least likely to contact a DOT meteorologist (only four responding agencies retain them) or consider previous forecast accuracy.

Most field personnel respondents reported comparing forecasts from multiple sources to reduce their uncertainty. Approximately two-thirds sought further information from neighboring jurisdictions or from NWS and paid forecasting services to increase certainty in the forecast. A few contacted a DOT meteorologist for more information.

Managing Maintenance Actions

Making Decisions on Maintenance Actions

Maintenance supervisors may employ a range of tools or practices to help make decisions on the maintenance actions needed for a specific weather forecast or road condition. More than three-quarters of central office respondents reported that field crew recommendations informed these decisions. These respondents were least likely to report the use of a decision tree or a meteorologist's recommendation.

Both central office staff and field personnel most often followed the practice of taking each other's recommendations. The proportion of respondents reporting the use of other decision-making tools also correlated closely between field personnel and central office staff. The most frequently used strategies for making maintenance decisions for both respondent groups:

- Follow recommendations of field personnel
- Follow recommendations of DOT staff
- Follow maintenance decision support system (MDSS) recommendations

Real-Time Adjustments to Maintenance Actions

During storm events, maintenance supervisors may need to adjust their directions to crews based on real-time pavement temperature data from truck sensors transmitted automatically by AVL or sensor systems on DOT vehicles. Almost half of central office respondents indicating a specific frequency for making these real-time adjustments seldom do so.

Field personnel provided no consensus on the frequency of making real-time adjustments to maintenance actions but did offer comments on agency practices. These comments revealed that changes are often made based on real-time data from sensors and/or video available to office staff. Data drive the real-time adjustments reported by both respondent groups.

Managing Weather Information

Conveying Weather Information

Communication between maintenance supervisors and operators in the field is critical to effectively address rapidly changing weather conditions. This communication may be in the form of changing

directives coming from maintenance supervisors to their operators in the field, or operators in the field reporting on rapidly changing weather conditions on the ground in real time.

Most central office survey respondents use radios, in-person communication and cell phones to convey new or changing weather information to operators in the field; none use in-cab messaging.

Field personnel favored cell phone use somewhat more than central office staff; text messaging was mentioned by some respondents in both groups. Field personnel generally used the same methods to report back to their supervisors from the field. Operators also use email and talk to one another in the field to keep informed of current conditions.

Improving Acquisition and Use of Weather Information
Respondents were asked to identify the most important changes their agencies could make to improve how weather information is acquired, used and translated into road maintenance actions by selecting from among a range of actions or practices. Improving or providing training were cited most frequently by central office and field personnel respondents. Only one central office respondent reported interest in subscribing to different paid forecasting services, and three states—Indiana, New Hampshire and West Virginia—reported interest in hiring a DOT meteorologist.

Many respondents recommended more frequent interaction with meteorologists. Both respondent groups concurred that developing closer ties to federal programs and partnering with nearby agencies would be beneficial.

Challenges to Improving Weather Information Acquisition and Use
Many respondents indicated a desire to improve their agencies' acquisition and use of weather information, and identified the key impediments to making positive changes. Costs and funding were cited by almost half of central office respondents identifying challenges; other central office respondents cited resistance to change and obtaining buy-in. Many field personnel respondents also reported challenges associated with costs and funding, and others described challenges with managing data, resistance to change, and technology-related needs or deficiencies.

Literature Search

Results of a literature search provide a sampling of research, guidance and other resources related to the acquisition and use of weather forecast information for winter road maintenance. Resources are grouped into three categories:

- Previous Clear Roads Research
- National Research and Guidance
- State and Local Agency Resources

Previous Clear Roads research that considered weather forecast information includes a 2019 project that analyzed mobile technologies for assessing road conditions; a second 2019 research effort modified the Accumulated Winter Season Severity Index tool to make it more useful to state DOTs.
National resources include FHWA's 2019 Road Weather Management Performance Measures Update and information about FHWA's Road Weather Program, which includes the Pathfinder program. Pathfinder is described as "a collaborative strategy for proactive transportation system management ahead of and during adverse weather events [that] encourages State departments of transportation

(DOTs), NWS and weather service contractors to share and translate weather forecasts and road conditions into consistent transportation impact messages for the public." FHWA's Weather-Savvy Roads Resource Toolkit offers guidance, including webinars, to help agencies be proactive in preparing for adverse weather events.

Also included is information about the Meteorological Assimilation Data Ingest System (MADIS) and a 2017 FHWA publication that describes the Pikalert System Vehicle Data Translator, which "assesses current weather and road conditions based on observations from connected vehicles, road weather information stations, radar and weather model analysis fields."

Publications from state and local agencies include a range of guidance related to RWIS:

- A June 2016 Aurora Program pooled fund study report examines RWIS network management.
- California's WeatherShare online repository provides RWIS data and weather information.
- Two FHWA publications describe Idaho Transportation Department's RWIS deployment.
- A January 2017 report uses a Minnesota case study to present an innovative approach to RWIS planning.
- Washington State Transportation Center developed a web-based RWIS application for use by state DOT personnel and the public.

Links to online weather-related sites maintained by Illinois, Iowa, Michigan and Washington illustrate how states are presenting weather data to the public. A 2019 Nebraska DOT newsletter describes the agency's collaboration with FHWA on a successful Pathfinder pilot project, and a 2016 FHWA report describes a partnership with Wyoming DOT to improve maintenance staff road condition reporting.

1 Introduction

A transportation agency's ability to deliver effective winter road maintenance combines three essentials: a professional, knowledgeable staff, including trained snowplow operators; a fleet of high-quality, well-maintained equipment and appropriate supplies; and, perhaps most important and most difficult to consistently acquire, accurate and timely weather information.

Sources of weather information for transportation agencies are many and varied. They range from local weather broadcasts and numerous national online weather data sources, such as websites and apps, to contract forecasting services and on-staff meteorologists. Many agencies also gather data from a local road weather information system (RWIS) and mobile advanced road weather information system (MARWIS) sensors on agency vehicles.

This synthesis project sought to determine the best practices agencies use to acquire accurate and timely weather information to strategize and deploy equipment for winter road maintenance operations. The project also examined the practices used to convey information about forecasts and road weather conditions between agency offices and operators in the field.

Two surveys directed to winter maintenance practitioners at Clear Roads member state departments of transportation (DOTs) gathered information about agency resources, practices and needs regarding the acquisition and use of accurate and timely weather information. One survey targeted staff members in agency central offices; the second survey was distributed to winter road maintenance field personnel selected by central office staff. The two surveys included the same questions, with one exception—an additional section in the central office staff survey addressed the use of an in-house meteorologist.

Survey results are presented separately in this synthesis report, beginning with central office staff responses below; field personnel survey findings begin on page 27. Results of a literature search, which begin on page 42, supplement survey findings.

2 Survey of Practice: Central Office Staff

2.1 Overview

An online survey sent to the 36 Clear Roads member agencies received responses from 22 states:

- Arizona
- Connecticut
- Delaware
- Idaho
- Indiana
- Kansas
- Massachusetts
- Michigan
- Minnesota
- Nevada
- New Hampshire
- Ohio
- Oregon
- Pennsylvania
- Rhode Island
- South Dakota
- Utah
- Vermont
- Washington
- West Virginia
- Wisconsin
- Wyoming

Survey questions examined practices used by central office staff to acquire and use weather-related information. Survey findings are presented below in five primary topic areas:

Information Sources
- Sources for Weather Forecasts
- Sources of Road Weather Conditions

Working with Meteorologists and Partners
- Agencies Employing an In-House Meteorologist
- Agencies Not Employing an In-House Meteorologist
- Agencies Considering Employing an In-House Meteorologist
- Engaging with Meteorologists
- Partnerships to Share Weather Condition and Forecasting Information

Managing Forecasts
- Assessing Weather Forecasts and Road Condition Information
- Managing Forecast Uncertainty

Managing Maintenance Actions
- Making Decisions on Maintenance Actions
- Real-Time Adjustments to Maintenance Actions

Managing Weather Information
- Conveying Weather Information
- Improving Acquisition and Use of Weather Information

The full text of the survey questions appears in Appendix A. The full text of the survey responses is available as an Excel file from the Clear Roads administrator.

2.2 Information Sources

Sources for Weather Forecasts

Respondents identified the sources of weather forecasts and conditions used by their agencies' maintenance supervisors when deciding when and where to mobilize crews for plowing, deicing, anti-icing and other winter maintenance activities. Table 1 presents survey responses.

Table 1. Sources for Weather Forecasts

State	ASOS, AWOS (FAA)[1]	Forecasts from Local TV News	In-House DOT Meteorologist	MADIS (NOAA)[2]	National Weather Service	Paid Weather Forecasting Service	Weather Website or App
Arizona		X		X	X		X
Connecticut		X			X	X	
Delaware					X	X	X
Idaho					X		
Indiana		X			X	X	
Kansas					X	X	X
Massachusetts		X			X	X	X
Michigan		X			X	X	
Minnesota	X	X			X	X	

State	ASOS, AWOS (FAA)[1]	Forecasts from Local TV News	In-House DOT Meteorologist	MADIS (NOAA)[2]	National Weather Service	Paid Weather Forecasting Service	Weather Website or App
New Hampshire		X			X		X
Nevada		X			X		X
Ohio		X			X	X	X
Oregon		X			X	X	
Pennsylvania		X			X	X	X
Rhode Island			X			X	X
South Dakota		X			X	X	
Utah			X				
Vermont					X		
Washington			X		X		X
West Virginia		X		X	X		
Wisconsin	X	X	X		X	X	X
Wyoming					X	X	X
Total	**2**	**14**	**4**	**2**	**20**	**14**	**12**

1 Automated Surface Observing Systems (ASOS) and Automated Weather Observing Systems (AWOS) are a joint effort between the Federal Aviation Administration (FAA) and the National Weather Service (NWS).

2 Meteorological Assimilation Data Ingest System (MADIS) ingests data from National Oceanic and Atmospheric Administration (NOAA) and non-NOAA providers.

Use of Paid Weather Forecasting Services, Weather Websites and Apps

State DOTs may acquire weather forecasts and related information from a variety of sources, including federal agencies and subscription-based weather services, websites and apps. Respondents reporting the use of a paid service most often use DTN, with some using that vendor's maintenance decision support system (MDSS). Table 2 summarizes survey responses. Monthly and annual costs are noted if provided.

Table 2. Paid Weather Forecasting Services, Weather Websites and Apps

State	Paid Weather Forecasting Service	Weather Website or App
Arizona[1]	N/R	AccuWeather
Connecticut	*CompuWeather*. Daily weather reports issued at 7 a.m. and 2 p.m. Weather warnings are issued as needed and updated every four hours during a storm event.	• AccuWeather • Intellicast (Weather Underground) • Lufft • NOAA • NWS
Delaware	Iteris (now DTN)	AccuWeather (premium)
Indiana	*DTN MDSS*. Used to assess treatment recommendations for individual routes and monitor forecasts. *Annual Cost*: $250,000.	N/R
Kansas	DTN	• AccuWeather • Local TV app

State	Paid Weather Forecasting Service	Weather Website or App
Massachusetts	*DTN MDSS*. Provides forecasts four times daily plus supplemental warnings.	DTN's mobile app
Michigan	*DTN MDSS*. Supervisors use MDSS across the state during the winter months to view weather and roadway forecasts. *Monthly Cost*: Approximately $43,000 during the winter months for forecasting and recommendations.	N/R
Minnesota	*DTN MDSS*. Provides dedicated route and regional weather forecasts, web and mobile MDSS applications, and a maintenance report interface. The agency's contract provides for a direct line to forecasters and interaction with the application forum.	N/R
New Hampshire	N/R	• Backyard Weather • Weather Underground • Weather.com
Nevada	N/R	• AccuWeather • WeatherWiz
Ohio[2]	*DTN:* • RotorWatch provides aviation-related forecasts. • Total View processes data from RWIS sensors. • WeatherSentry provides forecasts.	• Weather Bug • Weather Underground
Oregon	*ERF Company Inc*. Personalized weather forecasts for the district are provided by a meteorologist available to the respondent and other managers 24/7. *Annual Cost*: Approximately $4,000.	N/R
Pennsylvania	• DTN • Earth Sciences (*Note*: It is not clear if this is a university-based or private sector resource.)	• AccuWeather
Rhode Island	• DTN • Vaisala	• AccuWeather • NOAA
South Dakota	*DTN*. Provides hourly current and forecasted site-specific road and weather data. The agency uses DTN ClearPath Weather to plan for the severity of the storm and possible interstate closure.	N/R
Vermont	*Northern Vermont University*. Provides one daily forecast for each district during the workweek and for weekend storms. *Annual Cost*: $15,000.	N/R
Washington	N/R	• Local meteorologist blogs • Local news • Weather Underground
Wisconsin	*DTN MDSS.* Available through TPF-5(347) Development of Maintenance Decision Support System pooled fund study, which includes route forecasts and treatment recommendations. DTN is the study's MDSS vendor.	AccuWeather

State	Paid Weather Forecasting Service	Weather Website or App
Wyoming	• DayWeather Inc. • DTN MDSS	WeatherNet

N/R No response.

1 The respondent also noted that the agency uses RWIS and Road Weather Management Program data.

2 Real-time information is available from the agency's RWIS and MARWIS units, and its GPS/automatic vehicle location (AVL) system. (MARWIS road weather sensors are installed on vehicles to detect road conditions, temperatures, friction and other parameters.)

The respondent elaborated on the agency's forecasting support, noting that "[w]e receive forecasting support from DTN and NWS. During predicted large storm events, we will have [a] statewide conference call. We also [have] an anti-icing guideline, direct liquid application guideline and an application guideline."

Sources for Road Weather Conditions

Information about road weather conditions can be used to supplement weather forecasts. Respondents selected from among the following information sources to describe how their agencies supplement weather forecasts:

- Data from mobile sensors on DOT vehicles that detect pavement temperature, friction and other parameters
- Reports from plow drivers
- Reports from the public, including social media posts
- RWIS station data
- Video from traffic cameras or snowplow cameras
- Visual assessment

Respondents most frequently reported the use of RWIS station data and traffic or snowplow video data as resources for road weather condition information. Table 3 summarizes survey responses.

Table 3. Sources for Weather Information

State	DOT Vehicle Mobile Sensors	Reports from Plow Drivers	Public Reports	RWIS Station Data	Traffic or Snowplow Video	Visual Assessment
Arizona	X	X	X	X	X	X
Connecticut	X			X		X
Delaware	X	X		X	X	X
Idaho				X	X	X
Indiana	X	X		X	X	X
Kansas		X	X	X	X	X
Massachusetts[1]	X	X		X	X	
Michigan	X	X		X	X	X
Minnesota	X	X		X	X	X
New Hampshire				X	X	
Nevada	X	X		X	X	X
Ohio[2]	X	X	X	X	X	X

State	DOT Vehicle Mobile Sensors	Reports from Plow Drivers	Public Reports	RWIS Station Data	Traffic or Snowplow Video	Visual Assessment
Oregon	X	X	X	X	X	X
Pennsylvania		X	X	X	X	X
Rhode Island	X			X	X	
South Dakota	X	X	X	X	X	X
Utah		X		X	X	
Vermont	X			X	X	
Washington	X	X		X	X	X
West Virginia		X	X	X	X	X
Wisconsin	X	X		X	X	X
Wyoming	X	X	X	X		
Total	**16**	**17**	**8**	**22**	**20**	**16**

1 The agency also obtains weather condition information from state police alerts regarding icy conditions.

2 The agency uses information from MARWIS vehicle sensors.

2.3 Working with Meteorologists and Partners

Agencies Employing an In-House Meteorologist

Four states—Rhode Island, Utah, Washington and Wisconsin—employ an in-house meteorologist. Table 4 provides a high-level description of agency practices.

Table 4. Agency Practices for In-House Meteorologists

State	Employee/Contract Status	Duration of Service	Annual Cost	Previous Weather Forecasting Practice
Rhode Island	Full-time staff	4 years	Not provided	Local TV and NWS
Utah	Full-time staff	Not provided	Not provided	Not provided
Washington	Contractor/consultant	More than 15 years	$120,000	Not known
Wisconsin	Contractor/consultant	25 years	$130,000	Not provided

Respondents were asked to describe the value or benefits their agencies receive from having an in-house meteorologist by selecting from the following response options:

- Cost-effective when compared to other practices
- Greater confidence in forecasts from an in-house meteorologist than from other sources
- Increased access to a real person to address questions (compared with paid forecast services)
- In-house meteorologist can represent the agency to media, legislators, governor, etc.
- In-house meteorologist can serve as liaison to emergency management or traffic management center (TMC)
- Targeted forecasts that focus on what matters to the agency

Table 5 presents survey responses.

Table 5. Benefits of In-House Meteorologists

State	Cost-Effective	Greater Confidence	In-Person Access	Represent Agency	Liaison to Emergency Management or TMC	Targeted Forecasts
Rhode Island	X	X	X	X	X	X
Utah		X				
Washington	X	X	X		X	X
Wisconsin			X	X	X	

Three respondents expanded on their description of agency benefits:

- An in-house meteorologist's forecast accuracy is "tremendous" (Rhode Island).
- Crews can call the agency's contractor anytime 24/7 to get clarification on a weather forecast. This personal touch is invaluable when conflicting information exists (Washington).
- The agency uses an in-house weather expert to manage all DOT weather programs for both maintenance and operations (Wisconsin).

Agencies Not Employing an In-House Meteorologist

More than half of respondents cited other weather information sources and an uncertainty with regard to the benefits of retaining a meteorologist as the reasons for seeking weather information from sources other than an in-house meteorologist. Table 6 presents survey responses.

Table 6. Reasons for Not Employing an In-House Meteorologist

State	High Cost	Other Weather Information Sources	Satisfied with Weather Forecasting Contractor	Uncertain of Benefits
Arizona	X			X
Connecticut		X	X	X
Delaware		X		
Idaho		X		
Indiana				X
Kansas		X		X
Massachusetts		X	X	
Michigan			X	
Minnesota			X	
New Hampshire	X			X
Nevada	X	X		X
Ohio		X		
Oregon		X	X	X
Pennsylvania	X	X	X	X
South Dakota		X	X	

State	High Cost	Other Weather Information Sources	Satisfied with Weather Forecasting Contractor	Uncertain of Benefits
Vermont				X
West Virginia	X			X
Total	**5**	**10**	**7**	**10**

Some respondents elaborated on why their agencies have concluded that an in-house meteorologist is not needed or cannot be retained:

- *Arizona*. The respondent noted that the "state does get weather" but also indicated that it may not be "enough to have a full-time staff member."
- *Connecticut*. Ample weather information is available and the agency's contracted weather service is relatively inexpensive.
- *Idaho*. The agency has a strong relationship with NOAA and feels this is sufficient.
- *Minnesota*. The agency is under contract with DTN, which provides weather and road weather forecasting as part of an overall package. In-house forecasting would not be an advantage given the agency's current situation.
- *Pennsylvania*. The agency has ample outside weather sources, including "abundant" summer interns from Millersville University and Penn State University located near the agency's central office that take on minor assignments related to weather data. The primary reason to retain contracted forecasting is 24/7, on-demand service. The respondent noted "it would take a full staff of several to provide that level of service."
- *West Virginia*. There is interest by some in the agency, but not all. The respondent noted that "[p]ossibly, as the severity of winter weather seems to decrease, the focus [on] winter resources decreases."
- *Wyoming*. Paid services provide special weather forecasts when contacted by phone or email.

Agencies Considering Employing an In-House Meteorologist

Three states—Indiana, West Virginia and Wyoming—are considering employing an in-house meteorologist. Table 7 presents respondents' reasons for considering this change.

Table 7. Reasons for Considering an In-House Meteorologist

State	Cost-Effective	Greater Confidence	In-Person Access	Represent Agency	Liaison to Emergency Management or TMC	Targeted Forecasts
Indiana	X	X	X		X	X
West Virginia		X	X	X	X	X
Wyoming					X	

Engaging with Meteorologists

Even those agencies not retaining an in-house meteorologist reported some degree of engagement with a meteorologist. Respondents described their level of engagement with different types of meteorologists using a rating scale of 1 to 5:

- 1 = Never
- 2 = Seldom
- 3 = About half of storm events
- 4 = Usually
- 5 = Ever storm event

Respondents could also provide an "N/A" (not applicable) response.

Table 8 identifies the frequency with which respondents or other staff interact with a meteorologist and an average rating of responses. Respondents most frequently engage with a paid weather forecast service (slightly more often than for about half of storm events). Respondents reported the least amount of engagement with meteorologists associated with a partnership or coalition.

Table 8. Frequency of Interactions with Meteorologists

State	In-House Meteorologist	NWS Meteorologist	Paid Weather Forecast Service	Partnership or Coalition
Arizona	1	5	1	1
Connecticut	1	2	5	N/A
Delaware	N/A	N/A	2	N/A
Idaho	N/A	5	N/A	N/A
Indiana	N/A	3	2	3
Kansas	N/R	3	5	
Massachusetts	1	2	4	2
Michigan	N/A	1	4	4
Minnesota	N/A	2	3	N/A
New Hampshire	N/A	2	3	N/A
Nevada	N/A	3	N/A	N/A
Ohio	1	4	5	1
Oregon	N/A	3	5	N/A
Pennsylvania	N/A	2	4	3
Rhode Island	5	1	2	N/A
South Dakota	N/A	1	5	1
Utah	4	N/A	N/A	N/A
Vermont	N/A	3	2	1
West Virginia	N/A	4	1	4
Wisconsin	5	2	3	3
Wyoming	N/A	3	3	1
Average Rating	**2.57**	**2.68**	**3.28**	**2.18**

N/R No response.

Interactions with Meteorologists

Some respondents offered details of their interactions with meteorologists, often addressing the questions they ask and their satisfaction with the information provided. Table 9 presents respondents' comments about these interactions.

Table 9. Comments About Interactions with Meteorologists

State	Description of Interaction
Arizona	The respondent characterizes the agency's interaction with NWS as "outstanding."
Connecticut	Discussions with the agency's contracted weather service meteorologist address start and stop times, precipitation amounts, temperatures and more.
Indiana	The agency participates in calls with NWS or DTN when presented with several different forecasts or a higher level of uncertainty.
Massachusetts	Questions regarding onset and forecaster confidence level are most typical.
Michigan	Typically, the agency asks DTN to save data on a certain storm if the agency suspects it will need to review the response or performance by a particular garage or region.
Minnesota	Supervisors collaborate with DTN and NWS forecasters to determine when events will begin and end, most often to make decisions on split shifts and staffing. Ice events and blizzard warnings are more likely to generate calls to forecasters than a "run-of-the-mill" event.
Ohio	Previously, the agency communicated with some of the local TV weather forecasters. Currently, the agency asks its paid service provider (DTN) when the storm will arrive, what the precipitation will be when it comes in, how much the area can expect to receive, when it will stop, and when the winds will "lay down."
Pennsylvania	The agency's contract with AccuWeather includes on-demand briefings, on-demand statewide Webex meetings with department managers, and annual after action reports with the provider to review and correct any issues the agency has identified with the forecasting.
Rhode Island	The agency requires "constant updates with storms."
South Dakota	Issues addressed include projected accumulation, storm tracking and wind strength; the agency also notes what is actually experienced versus what is forecasted.
West Virginia	Timing-specific questions address morning and evening commutes, especially regarding transition of precipitation.
Wisconsin	Discussions address the agency's confidence level in start time and amounts, or advising that the forecast isn't accurate. DTN, the agency's provider, is "very responsive."
Wyoming	The agency contacts DTN, its MDSS provider, to share changes in the forecast as it happens, usually receiving a revised forecast within minutes.

Partnerships to Share Weather Condition and Forecasting Information

Some responding agencies participate in a partnership or coalition with other agencies or organizations to share information about weather conditions and forecasts. Table 10 summarizes survey responses.

Table 10. Agency Partnerships or Coalitions

Partner	State	Description
Emergency Management	Connecticut	The state's Emergency Management Office provides weather forecasting during storm events.
	Pennsylvania	The DOT works with the state's Emergency Management Agency, which retains a staff meteorologist.
FHWA Pathfinder	Minnesota	FHWA's Pathfinder initiative offers access to the MnDOT Pathfinder chat room and allows for interaction between users and forecasters.
	West Virginia	The respondent noted that the agency participates in the Pathfinder project but did not provide details.
National Weather Service	Arizona	The agency shares or will begin sharing RWIS data with NWS.
	Indiana	The agency maintains NWS office partnerships with each of its districts.
NOAA	Washington	The agency partners with NOAA through its contractor, WeatherNet, which works directly with NOAA to collaborate and compare forecasts and interpret models.
Pooled Fund Study	Michigan, Wisconsin	These states participate in the TPF-5(347) Development of Maintenance Decision Support System pooled fund study. DTN is the study's MDSS provider.
Other National, State or Local Agencies	New Hampshire	The agency shares information with the Department of Safety and Homeland Security.
Other Partners	Indiana	• Indiana Silver Jackets • Indiana Mesonet
	Washington	Northwest Avalanche Center (mountain forecasts).

2.4 Managing Forecasts

Assessing Weather Forecasts and Road Condition Information

Respondents were asked to rate their level of confidence in the weather forecasts and condition information their agencies receive from a variety of information sources. When providing these ratings, respondents considered past experiences as well as current sources of weather information, rating each information source using the following rating scale:

- 1 = Not at all confident
- 2 = Slightly confident
- 3 = Moderately confident
- 4 = Very confident
- 5 = Extremely confident

Respondents could also choose from "Don't know" and "Haven't used" response options.

The four agencies with in-house meteorologists reported a high level of confidence in the weather forecasts provided by those meteorologists. For agencies not retaining an in-house meteorologist, paid weather forecasting services, and forecasts from NWS and FAA's ASOS and AWOS, garnered the highest ratings from the respondents using these services. Table 11 provides individual survey responses and an average rating of responses.

Table 11. Confidence in Weather Forecast Information Sources

State	ASOS, AWOS (FAA)	Local TV News Forecasts	In-House DOT Meteorologist	MADIS (NOAA)	NWS	Paid Weather Forecasting Service	Weather Website or App
Arizona	Haven't used	1	Haven't used	Haven't used	4	Haven't used	3
Connecticut	Haven't used	4	Haven't used	Haven't used	4	5	4
Delaware	Haven't used	3	Haven't used	Haven't used	3	3	3
Idaho	Haven't used	Haven't used	Haven't used	Haven't used	5	Haven't used	Haven't used
Indiana	Haven't used	2	Haven't used	3	4	3	2
Kansas	3	3	Haven't used	Haven't used	3	3	3
Massachusetts	Haven't used	3	Haven't used	3	3	4	4
Michigan	4	3	Haven't used	4	4	4	3
Minnesota[1]	Don't know	3	Don't know	Don't know	4	4	3
New Hampshire	N/R	3	N/R	N/R	4	N/R	3
Nevada	N/R	3	N/R	N/R	3	3	3
Ohio	Haven't used	4	Haven't used	3	4	4	4
Oregon	Haven't used	3	Haven't used	Haven't used	4	5	3
Pennsylvania[2]	3	3	Haven't used	2	4	5	5
Rhode Island	Haven't used	1	5	Haven't used	2	2	Haven't used
South Dakota	4	3	Haven't used	5	5	5	4
Utah	Don't know	3	5	4	4	Don't know	Don't know
Vermont[3]	Haven't used	4	Haven't used	Haven't used	4	4	4
Washington[4]	Haven't used	2	4	Haven't used	4	Haven't used	2
West Virginia	Haven't used	1	Haven't used	3	4	3	2
Wisconsin	5	2	5	Haven't used	4	4	2
Wyoming	4	3	Haven't used	3	4	5	5
Average Rating	**3.83**	**2.76**	**4.75**	**3.28**	**3.76**	**3.93**	**3.33**

N/R No response.

1 The agency mostly uses MDSS.

2 The agency also uses RWIS and is very confident in the weather information provided.

3 Northern Vermont University "is about the same with consistency and accuracy in weather forecasts," which gives the agency "a good idea of what might happen in each district."

4 Northwest Avalanche Center (https://www.nwac.us/weatherdata/washingtonpass/now/) is used for mountain and avalanche forecasts. The respondent notes that these forecasts "are very accurate in this environment" and is very confident in the forecasts provided.

Other Experiences with Weather Forecasting Resources

Some respondents described their experiences with weather forecasting resources that did not match agency needs. Table 12 summarizes survey responses.

Table 12. Other Experiences with Weather Forecasting Resources

State	Comments
Idaho	The agency used contractors but realized NWS was better suited to its location and the forecasts offered greater accuracy.
Indiana	AccuWeather and a local vendor provided demonstrations of their services, however the same data was already available from other agency sources.
New Hampshire	The agency had used MDSS but found that the weather forecast "was off most of the time" and agency staff were not responsive to requests to enter data into the system.
Vermont	The agency works with Vermont Electric Coop and IBM to establish weather forecasting for potential electrical outages using the agency's own RWIS station data.
Wyoming	Approximately 20 years ago, the agency retained DTN to provide weather forecasts for individual shop locations. The forecasts gave no consideration for elevation change or mountains the weather had to cross to get to the center of the state and were not specific to individual shops. The respondent characterized the forecasts as a "NWS forecast that moved across the state" and simply changed start times for storm impacts.

Some respondents commented on weather information sources they'd like to try:

- Virtual RWIS (Arizona).
- Paid forecasting services Vaisala or Iteris on a trial basis (Utah).
- MDSS, to see how it might complement or supplement existing weather information or provide efficiencies (Vermont).
- Local NWS (Wyoming).

Managing Forecast Uncertainty

Respondents described how maintenance supervisors manage uncertainty about forecast accuracy by selecting from among several practices. Eighty-five percent of respondents compare multiple forecasts, while almost two-thirds contact NWS or a paid forecast service. Respondents were least likely to contact a DOT meteorologist (only four responding agencies retain them) or consider previous forecast accuracy. Table 13 summarizes survey responses.

Table 13. Managing Uncertainty About Forecast Accuracy

State	Compare Multiple Forecasts	Contact DOT Meteorologist	Contact NWS or Paid Forecast Service	Contact Neighboring Jurisdictions	Consider Previous Forecast Accuracy
Arizona[1]	X		X		
Delaware	X				
Idaho				X	
Indiana	X		X	X	
Kansas	X		X	X	

State	Compare Multiple Forecasts	Contact DOT Meteorologist	Contact NWS or Paid Forecast Service	Contact Neighboring Jurisdictions	Consider Previous Forecast Accuracy
Massachusetts	X		X	X	
Michigan	X			X	X
Minnesota	X		X	X	
New Hampshire	X				
Nevada	X		X		
Ohio	X		X	X	X
Oregon	X		X	X	X
Pennsylvania	X			X	X
Rhode Island		X			
South Dakota	X		X	X	
Utah	X				
Vermont			X		
West Virginia	X				X
Wisconsin	X	X	X	X	X
Wyoming	X		X		X
Total	**17**	**2**	**12**	**11**	**7**

1 In addition to the practices noted above, Arizona DOT's maintenance supervisors also contact the agency's storm room monitor.

2.5 Managing Maintenance Actions

Making Decisions on Maintenance Actions

Maintenance supervisors may employ a range of tools or practices to help make decisions on the maintenance actions needed to respond to a specific weather forecast or road condition. More than three-quarters of respondents reported that field crew recommendations informed these decisions. Respondents were least likely to report the use of a decision tree or a meteorologist's recommendation. Table 14 presents survey responses.

Table 14. Maintenance Decision Tools and Practices

State	Decision Tree	MDSS	Field Crew Recommendations	Meteorologist Recommendations	DOT Staff Recommendations
Arizona[1]					
Connecticut					X
Delaware					X
Idaho	X				
Indiana		X	X		X
Kansas	X		X		X
Massachusetts[2]		X	X	X	X
Michigan	X	X	X		
Minnesota		X	X		X

State	Decision Tree	MDSS	Field Crew Recommendations	Meteorologist Recommendations	DOT Staff Recommendations
New Hampshire			X		
Nevada			X	X	
Ohio[3]			X		X
Oregon			X	X	X
Pennsylvania			X	X	X
Rhode Island		X	X	X	X
South Dakota		X			
Utah	X		X		
Vermont			X		
West Virginia			X		X
Wisconsin		X	X		
Wyoming		X	X		
Total	**4**	**8**	**16**	**5**	**11**

1 Instead of the options presented in the survey, the agency uses RWIS data, road and atmospheric temperatures, and AVL.

2 The agency also uses RWIS and camera observations.

3 Maintenance supervisors also use their own historical knowledge.

Real-Time Adjustments to Maintenance Actions

During storm events, maintenance supervisors may need to adjust their directions to crews based on real-time pavement temperature data from truck sensors transmitted automatically by AVL or sensor systems on DOT vehicles. Almost half of respondents indicating a specific frequency for making these real-time adjustments seldom do so. Table 15 summarizes survey responses.

Table 15. Frequency of Real-Time Adjustments to Maintenance Actions

Frequency	State
Every storm event	Arizona, Pennsylvania, South Dakota
About half of storm events	Indiana, Utah, Wisconsin
Usually	Nevada, Rhode Island, Vermont
Seldom	Connecticut, Delaware, Idaho, Massachusetts, Minnesota, New Hampshire, Ohio, Oregon
Not sure/don't know	Michigan, Wyoming
Not applicable	Kansas, West Virginia

Table 16 provides additional details respondents offered about the decisions maintenance supervisors make when real-time weather data redirects maintenance actions in the field.

Table 16. Comments About Real-Time Adjustments to Maintenance Actions

State	Comments
Arizona	Snowplow drivers look at current road conditions and temperatures when applying material.
Massachusetts	The agency is installing mobile road weather and condition grip friction sensors as part of its plan to move away from roadway treatments based on temporal rhythms and use real-time physical parameters to indicate the next treatment, if any.
Minnesota	Adjustments would likely be required in rare situations such as wind events and freezing rain/drizzle. Typically, operators can make most decisions in the truck based on recommendations and conditions.
Ohio	Previously, agency trucks had on-board pavement and air temperature sensors that were removed due to issues with truck fires. These issues have been resolved and the sensors are being reinstalled. The agency's winter maintenance manager uses images from snowplows to make decisions. A manager can review photos of routes and make the decision to send crews home or move them to areas with a greater need.
Pennsylvania	All assistant managers and managers have access to speed and RWIS data. These information sources as well as CCTV assist with on-the-spot decisions made by field personnel about conditions on the ground, as well as the decisions made by central office management viewing overall network conditions.
Rhode Island	Information is passed back to the in-house meteorologist.
South Dakota	The agency uses data to achieve its level of service, which may mean bringing in seasonal and reservist operators.
Wisconsin	Almost all trucks are outfitted with pavement temperature sensors that supervisors monitor and adjust.

2.6 Managing Weather Information

Conveying Weather Information

Communication between maintenance supervisors and operators in the field is critical to effectively address rapidly changing weather conditions. This communication may be changing directives coming from maintenance supervisors to their operators in the field, or operators in the field reporting on rapidly changing weather conditions on the ground in real time.

Most survey respondents use radios, in-person communication or cell phones to convey new or changing weather information to operators in the field; none use in-cab messaging. Table 17 summarizes survey responses.

Table 17. Communication Methods: Supervisors to Field Operators

State	Cell Phone	In Person	Radio	Text Message
Arizona	X		X	
Connecticut	X	X	X	X

State	Cell Phone	In Person	Radio	Text Message
Delaware	X		X	X
Idaho	X	X	X	X
Indiana		X	X	
Kansas				
Massachusetts	X	X	X	
Michigan		X	X	
Minnesota[1]		X	X	
New Hampshire	X	X	X	
Nevada	X	X	X	
Ohio[2]	X	X	X	
Oregon	X	X	X	X
Pennsylvania	X	X	X	
Rhode Island	X	X	X	
South Dakota		X	X	
Utah	X	X	X	
Vermont		X	X	
West Virginia	X	X	X	
Wisconsin			X	
Wyoming	X		X	X
Total	**14**	**16**	**20**	**5**

1 MDSS will update its recommendation based on changing conditions and allows operators to make changes to the information provided via the AVL screen in the truck.

2 The agency uses a grease board in the shop. When drivers return, they look for guidance on the board. Cell phones are used very sparingly given the state's cell phone use laws.

Field operators are slightly less likely to use in-person communication than their central office colleagues when initiating communications to the central office. Table 18 summarizes survey responses.

Table 18. Communication Methods: Field Operators to Supervisors

State	Cell Phone	In Person	Radio	Text Message
Arizona	X	X	X	X
Connecticut	X	X	X	X
Delaware	X		X	X
Idaho	X	X	X	X
Indiana		X	X	
Kansas	X		X	
Massachusetts	X		X	X
Michigan			X	
Minnesota	X		X	
New Hampshire	X	X	X	

State	Cell Phone	In Person	Radio	Text Message
Nevada	X	X	X	
Ohio[1]	X	X	X	X
Oregon	X	X	X	X
Pennsylvania	X		X	
Rhode Island	X	X	X	
South Dakota		X	X	
Utah	X		X	X
Vermont		X	X	
West Virginia	X	X	X	
Wisconsin			X	
Wyoming	X		X	
Total	**16**	**12**	**21**	**8**

1 Operators text and use cell phones only when vehicles operated under a commercial driver's license are parked.

Improving Acquisition and Use of Weather Information

Respondents were asked to identify the most important changes their agencies could make to improve how weather information is acquired, used and translated into road maintenance actions by selecting from among a range of actions or practices. Improving or providing training were cited by the most respondents. Only one respondent reported interest in subscribing to different paid forecasting services, and three states—Indiana, New Hampshire and West Virginia—reported interest in hiring a DOT meteorologist. Tables 19 and 20 present survey responses.

Table 19. Changes to Improve Acquisition and Use of Weather Information

State	Engage with Federal Programs and Initiatives	Partnerships with Other Agencies	Hire a DOT Meteorologist	More Frequent Interaction with Meteorologists	Provide MDSS or Other Decision-Making Aid	Improve MDSS or Other Decision-Making Aid
Arizona	X	X			X	
Connecticut	X				X	
Idaho		X				
Indiana	X		X			X
Kansas				X		
Massachusetts[1]				X		X
Michigan					X	X
Minnesota				X		X
New Hampshire	X	X	X	X		
Ohio[2]		X		X		
Rhode Island				X		X
South Dakota				X	X	X
Utah					X	X

State	Engage with Federal Programs and Initiatives	Partnerships with Other Agencies	Hire a DOT Meteorologist	More Frequent Interaction with Meteorologists	Provide MDSS or Other Decision-Making Aid	Improve MDSS or Other Decision-Making Aid
Vermont	X				X	
West Virginia	X	X	X		X	
Wyoming	X			X		X
Total	**7**	**5**	**3**	**8**	**7**	**8**

1 Employ more mobile RWIS devices.

2 Evaluate weather forecasts from a number of sources for a couple of years. Score the forecasts on accuracy and determine which source or sources score the highest.

Table 20. Changes to Improve Acquisition and Use of Weather Information (continued)

State	Provide Training	Improve Training	Subscribe to Different Paid Forecasting Services
Arizona	X	X	
Delaware		X	X
Idaho		X	
Kansas	X	X	
Michigan	X	X	
New Hampshire	X		
Ohio	X	X	
Oregon		X	
Pennsylvania		X	
South Dakota	X	X	
Vermont		X	
West Virginia	X		
Wisconsin	X	X	
Wyoming	X		
Total	**9**	**11**	**1**

Challenges to Improving Weather Information Acquisition and Use

Many respondents indicated a desire to improve their agencies' acquisition and use of weather information, and identified the key impediments to making positive changes. Costs and funding were cited by almost half of respondents identifying challenges; others cited resistance to change and obtaining buy-in. Table 21 summarizes survey responses.

Table 21. Challenges to Improving Weather Information Acquisition and Use

Issue	State	Description
Accuracy	Ohio	The respondent noted that "[w]hen a manager acts on a weather forecast and the forecast is blown, the manager has a rough time believing in the forecaster's future predictions. Improving weather forecasting accuracy would be our first step, then teaching the managers to trust and use the forecast is next."
Costs and Funding	Arizona, Indiana, Massachusetts, Michigan, Rhode Island, South Dakota, Vermont, West Virginia	*Arizona*. Budgets are always a challenge. *Indiana*. Cost is the number one challenge right now. *Massachusetts*. Cost is one, but FHWA is giving State Transportation Innovation Council (STIC) grants to entities wishing to beef up their road weather game. *Michigan*. Probably money. *Rhode Island*. Cost of equipment. *South Dakota*. Budget. *Vermont*. Cost versus benefit of some of the other information sources such as MDSS. *West Virginia*. Funding and resources.
Data Management	Pennsylvania	Controlling and making sense of the huge amounts of data the agency receives.
Obtaining Buy-In	Michigan, South Dakota	*Michigan*. Overall buy-in. *South Dakota*. Buy-in from maintenance workers on the utility of MDSS and AVL systems.
Resistance to Change	Utah, Wyoming	*Utah.* Personnel in the field who are reluctant to change. *Wyoming.* The respondent reported this attitude: *We have done it this way for the past 20 years. Why should I change?* Field personnel may not recognize that a change "will make their lives better."
Technology	Minnesota, Nevada	*Minnesota*. Improving the development of MDSS and noninvasive road sensors; using friction readings in MDSS modeling. *Nevada*. Deploying more units with AVL.
Training	Ohio	The respondent noted that his agency "can always use more training on the use of weather forecasts. Every year we have new managers that need to be trained."

3 Survey of Practice: Field Personnel

3.1 Overview

Clear Roads members identified potential respondents to a survey of field personnel that solicited, for the most part, the same type of feedback provided by their central office counterparts on the use of weather forecasting resources. Each Clear Roads member agency identified a maximum of seven potential respondents. Sixty-two field personnel respondents from 17 states responded to the survey:

- California
- Colorado
- Delaware (4 responses)
- Idaho (2 responses)
- Indiana (10 responses)
- Kansas (4 responses)
- Massachusetts
- Montana
- Nevada (3 responses)
- New York (8 responses)
- Ohio (5 responses)
- Pennsylvania (9 responses)
- South Dakota (6 responses)
- Texas
- Utah
- Washington (3 responses)
- Wyoming (2 responses)

The field personnel survey included the same questions as the central office survey with one exception—field personnel were not asked about the use of an in-house meteorologist. Survey findings are presented below in four primary topic areas:

Information Sources
- Sources for Weather Forecasts
- Sources for Road Weather Conditions
- Engaging with Meteorologists

Managing Forecasts
- Assessing Weather Forecasts and Road Condition Information
- Managing Forecast Uncertainty

Managing Maintenance Actions
- Making Decisions on Maintenance Actions
- Real-Time Adjustments to Maintenance Actions

Managing Weather Information
- Conveying Weather Information
- Improving Acquisition and Use of Weather Information

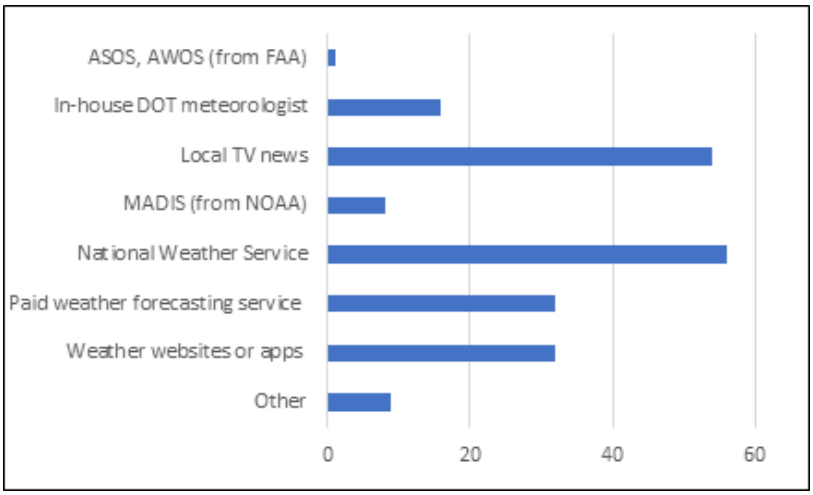
3.2 Information Sources

Sources for Weather Forecasts

Field personnel identified the sources of weather forecasts and conditions used by their agencies' maintenance supervisors to decide when and where to mobilize crews for plowing, deicing, anti-icing and other winter maintenance activities from among a series of options. Most respondents acquire weather information from NWS and local television news (90% and 87%, respectively), while approximately half of respondents reported using weather websites or apps or a paid weather

forecasting service. Approximately 26% of the 62 respondents reported that their agency has an in-house DOT meteorologist. Figure 1 summarizes survey responses.

Figure 1. Sources for Weather Forecasts



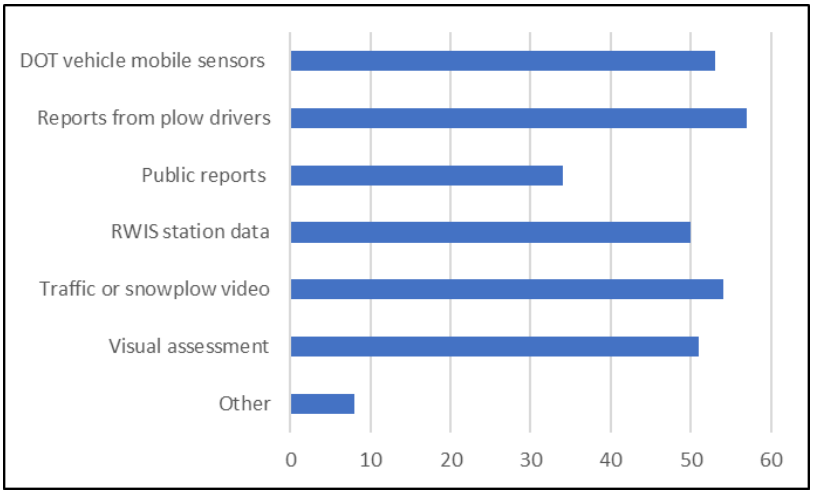
Sources for Road Weather Conditions

Field personnel identified the sources their agencies use to gather information about road weather conditions that supplement weather forecasts from among these options:

- Data from mobile sensors on DOT vehicles that detect pavement temperature, friction and other parameters
- Reports from plow drivers
- Reports from the public, including social media posts
- RWIS station data
- Video from traffic cameras or snowplow cameras
- Visual assessment

Most respondents use of all of these information sources but are least likely to use public reports as a source for weather information. Figure 2 summarizes survey responses.

Figure 2. Sources for Road Weather Condition Data



Some respondents offered information about other sources for road weather conditions. Table 22 summarizes survey responses.

Table 22. Supplemental Sources of Weather Information

State/Respondent	Information Source
Indiana 8	Require supervisors to run roads frequently during events to monitor road condition and adjust as needed. Also use good radio communications between subdistricts to warn of incoming weather.
New York 4	Local, county and state police.
New York 6	Supervisors patrolling roads.
Pennsylvania 4	Road views; Chester County Emergency Operations Center's Web Active Incident website; and municipality and police radio calls.
Pennsylvania 8	Contact neighboring counties and state to identify current weather conditions.
South Dakota 5	WebMDSS
Washington 2	Section reviews

Engaging with Meteorologists

Even those respondents from agencies not retaining an in-house meteorologist reported some degree of engagement with a meteorologist. Respondents described their level of engagement with different types of meteorologists using a rating scale of 1 to 5:

- 1 = Never
- 2 = Seldom
- 3 = About half of storm events
- 4 = Usually
- 5 = Every storm event

Respondents could also provide an "N/A" (not applicable) response.

Table 23 provides an average rating for the frequency of respondents' engagement with different types of meteorologists. Field personnel respondents are most likely to engage with a meteorologist from a paid weather service and least likely to interact with an in-house meteorologist. All of the meteorologist types are contacted in connection with fewer than half of storm events.

Table 23. Frequency of Interactions with Meteorologists

Type of Meteorologist	Average Rating
In-House Meteorologist	2.03
NWS Meteorologist	2.63
Paid Weather Forecast Service	2.98
Partnership or Coalition	2.76

Interactions with Meteorologists

Table 24 presents respondents' comments about their interactions, or the interactions of other staff, with meteorologists.

Table 24. Comments About Interactions with Meteorologists

State/Respondent	Description of Interaction
Idaho 2	The agency has weather briefings with NOAA every Monday and Thursday from November through April.
Indiana 5	Periodic phone calls will be made to validate conditions and accuracy of what staff members see in the field.
Indiana 7	Typically, storm planning will involve a call with NWS within 24 hours of a storm. Additional calls will continue as needs change or forecast information is "not sound."
Indiana 8	The agency will communicate with Iteris to inquire about confidence levels of severe storms and snow totals or to inform of missed forecasts.
Kansas 1	Information gathered is most often the start and end timing of events; also timing of significant changes during an event.
Massachusetts	If confidence is low on a particular forecast, the agency will check in to get start times and intensities, or call to get updated end times of events and updates for lake-effect events.
Montana	The agency has a good relationship and works closely with NWS during most storm events.
Nevada 1	NWS has been very responsive and will provide focused information when requested.
Nevada 2	Most meteorologists' concern is with snow total. The agency is more concerned with road snow and pavement temperatures in locations where it is hard to forecast.
Nevada 3	The agency gathers information on timing, severity and accumulation. The respondent notes that "probably 75% of the time we get good information."
New York 1	Listen in on statewide conference calls for more significant weather events.
New York 2	NWS meteorologists are included in agency storm briefings. Typical questions address timing of the storm's arrival, storm duration and intensity. The information provided is almost always useful and correct, and is a key factor in how the agency stages resources and attacks a storm event. For major snow events, the agency frequently engages with a meteorologist as management is constantly provided with up-to-the date information. Managers communicate this information to staff in the office and the field using conference calls.
New York 8	Usually conference calls with a meteorologist.
Ohio 2	Emailing the meteorologist.
Ohio 3	Questions posed relate to timing of the event, impacts to the traveling public and treatment recommendations. The respondent noted that "[t]hey usually provide very good responses that are accurate for our location."
Ohio 5	The agency discusses model output and forecast confidence, impact of the expected event, and what "can go wrong with the forecast." Information gathered includes precipitation type, amounts and timing.
Pennsylvania 1	Email forecasts are well written and include all necessary information, but the respondent noted that these forecasts are "not very accurate for our area."

State/Respondent	Description of Interaction
Pennsylvania 4	The respondent queries AccuWeather about start and end times, how much more accumulation can be expected, dry or wet snow, wind associated with drifting, ambient temperature and road temperature after the event.
Pennsylvania 5	The agency hosts winter Webex meetings before each event with a meteorologist available to give a prediction and answer questions.
Pennsylvania 6	Issues discussed include start times of precipitation, start times of change in precipitation types, snowfall rates per hour, sleet rates per hour, end times for precipitation, total accumulation on roadways, and locational differences associated with large elevation changes and precipitation types.
South Dakota 4	The agency uses WebMDSS and its meteorologist-provided information during every storm, providing feedback electronically via in-truck mobile data computer (MDC) units so forecasts can be adapted and corrected based on real-time information in the field.
Texas	The Texas Division of Emergency Management meteorologist has been extremely helpful in the agency's planning. Having access to his input is one reason the DOT has not considered hiring its own meteorologist.
Utah	The agency relies on only Weathernet for road weather information. Too many sources can lead to confusion and lack of trust, especially from sources not focused on transportation. Two agency meteorologists assist, facilitate, communicate and administer within the Utah DOT Weather Program. Weathernet's 10+ meteorologists are hired to provide road weather information. The agency logs over 5,000 interactions a year pertaining to road weather information as well as written forecasts.
Wyoming 2	When talking to the DOT or NWS, it is mostly about the timing of the events; the forecast may "be way off or all together incorrect."

3.3 Managing Forecasts

Assessing Weather Forecasts and Road Condition Information

Respondents' level of confidence in the weather forecasts and condition information their agencies receive from a variety of information sources is described in Table 25. When providing these ratings, respondents considered past experiences as well as current sources of weather information, rating each information source using the following rating scale:

- 1 = Not at all confident
- 2 = Slightly confident
- 3 = Moderately confident
- 4 = Very confident
- 5 = Extremely confident

Respondents could also choose from "Don't know" and "Haven't used" response options.

Forecasts from NWS and an in-house meteorologist garnered the highest ratings. Respondents reported the least confidence in forecasts from local TV news. Table 25 provides an average rating of responses.

Table 25. Confidence in Weather Forecast Information Sources

Information Source	Average Rating
National Weather Service	3.67
In-house DOT meteorologist (staff or consultant)	3.37
Paid weather forecasting service such as AccuWeather or DTN	3.31
ASOS, AWOS (from FAA)	3.29
MADIS (from NOAA)	3.17
Weather websites or apps	3.13
Forecasts from local TV news	2.88

Some field personnel respondents offered additional comments about the confidence level associated with weather information sources. Table 26 presents these responses.

Table 26. Comments About Confidence in Weather Forecast Information Sources

State/Respondent	Comments
Colorado	MADIS is more of a nowcasting platform with current conditions.
Indiana 7	NWS and MDSS are primary information sources.
Kansas 1	The respondent noted that there "are a sufficient [number] of forecasting tools and resources available to our staff. Many times 10-20 miles can make or break a forecast We typically start to gear up 24-48 hours out depending on a forecast but the 6 hour window in advance of an event is the most crucial in the prediction forecast window."
New York 1	Weather Underground has "a fantastic 7-day forecast graph."
New York 3	In the past the agency had access to the AccuWeather Professional paid service, which was very useful. The current Mesonet service is also very useful.
New York 6	AccuWeather Professional "was great while we paid for the service."
Ohio 1	Driver feedback and cameras in each truck help operators identify conditions everywhere and are very helpful in producing "high confidence."
Pennsylvania 1	The local WGAL Weather 8 is the best and most accurate forecast for the respondent's area.
Pennsylvania 4	The respondent reported texting DTN to get the most updated weather-related information.
Pennsylvania 8	Agency forecasts are for a larger area than a local forecast. Using an app or website with a specific location provides a more accurate forecast.
South Dakota 1	The respondent tracks multiple sites, including MDSS, Weather Bug, Keloland and social media, to identify precipitation amounts in various locations when an event starts.
South Dakota 2	The respondent noted that he is very confident in MDSS weather forecast data.
South Dakota 4	The respondent noted that "the best site I use is WebMDSS. It has data that I trust the most."

State/Respondent	Comments
Texas	The respondent is extremely confident in the forecasts provided the Texas Department of Emergency Management meteorologist.
Utah	The respondent noted that "[r]oad weather forecasting is the only service that is valuable. Other forecast information does not provide the information needed to make good decisions. There is a huge advantage to having forecasters inside the organization."
Wyoming 2	WYDOT TMC Live map is usually good source of information for forecasts and road conditions. [The respondent did not provide a link to this resource.]

Other Experiences with Weather Forecasting Resources

Some respondents described experience or trials with other weather forecasting resources. Table 27 summarizes survey responses.

Table 27. Other Experiences with Weather Forecasting Resources

State/Respondent	Comments
Indiana 4 and 10	Bam Wx weather forecasts were highly inaccurate.
Indiana 5	Trials with AccuWeather Bam Wx.
New York 3 and 8	DTN was tried but not found useful.
South Dakota 1	While the DTN service wasn't used very much, the respondent "like[d] their long range forecasts."
Wyoming 2	Components of the Iwapi AWOS system were not able to withstand truck vibration.

Respondents also commented on weather information sources they'd like to try. Table 28 presents survey responses.

Table 28. Weather Information Sources of Interest

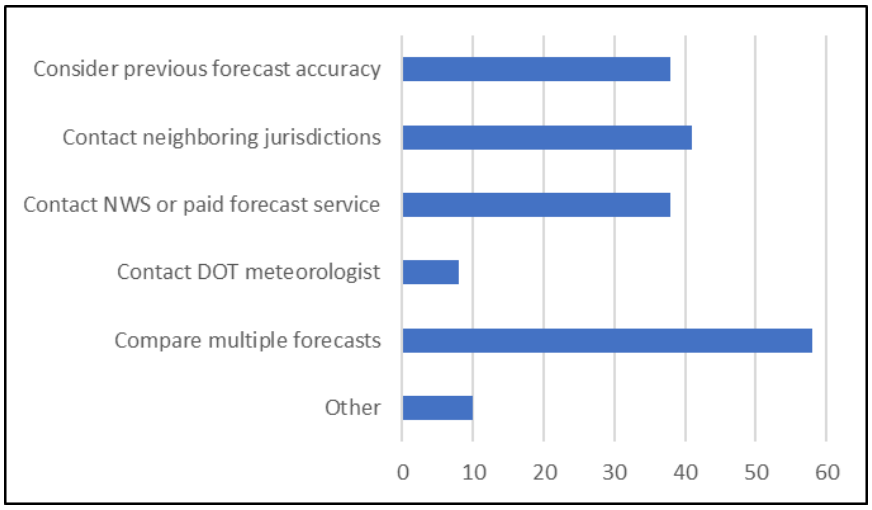
State/Respondent	Comments
Colorado	The agency is interested in running the Pikalert system (next-generation MDSS).
Massachusetts	More RWIS sites with current weather info and pavement conditions as well as cameras throughout the district are needed.
New York 6	The respondent expressed interest in AccuWeather Professional.
Pennsylvania 4	The respondent expressed interest in testing a system that allows for entry of real-time weather data to generate data on the time and number of trucks needed to manage an event. Such a system could help less experienced winter maintenance managers.
Pennsylvania 8	The respondent recommended independent actions such as more localized RWIS sites and web cameras at stockpile locations to view each location and gather weather information that can help the agency "make a better call for operators and equipment."

State/Respondent	Comments
Texas	The agency is considering using AccuWeather's paid service and finding ways to gain wider access to remote weather stations.
Utah	Current projects are investigating the use of connected vehicle information.

Managing Forecast Uncertainty

Respondents described how maintenance supervisors manage uncertainty about forecast accuracy. Most compared forecasts from multiple sources to reduce their uncertainty. Approximately two-thirds sought further information from neighboring jurisdictions or from NWS and paid forecasting services to increase certainty in the forecast. A few contacted a DOT meteorologist for more information. Figure 3 summarizes survey responses.

Figure 3. Managing Uncertainty About Forecast Accuracy



3.4 Managing Maintenance Actions

Making Decisions on Maintenance Actions

Field personnel identified the tools and practices their agencies' maintenance supervisors use to help make decisions on the maintenance actions needed for a specific weather forecast or road condition.

Both central office staff and field personnel most often followed the practice of taking each other's recommendations. The proportion of respondents reporting the use of other decision-making tools also correlated closely between field personnel and central office staff. Figure 4 summarizes field personnel survey responses.

Figure 4. Maintenance Decision Tools and Practices

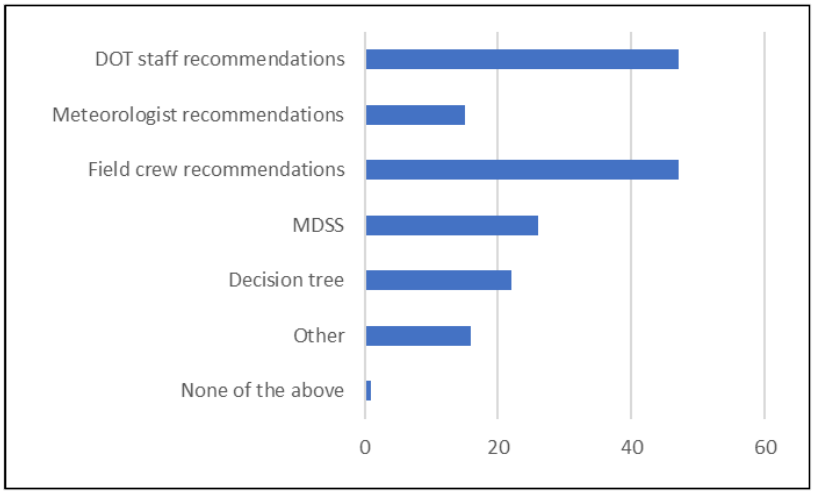


Table 29 provides details of respondents' other decision-making practices.

Table 29. Other Decision-Making Practices

State/Respondent	Description of Practice
Indiana 9	District management team discussion.
Kansas 1	DTN/WeatherSentry gives guidance or recommendations for forecasted conditions.
Massachusetts	Experience from past events and guidance from headquarters for very large events.
Nevada 1	Selected MDSS associated with the agency's snow plan, which includes detailed information about maintenance strategies and level of service dictated by route and priority.
Nevada 3	Operator experience.
New York 3	Road geometry, tree cover, bridges and traffic volume.
New York 4	Direction from regional office.
New York 6	Supervisors patrolling roads.
Ohio 1	While the agency has a decision tree, "experience usually dictates what to do for the specific weather."
Pennsylvania 4	The respondent indicated interest in MDSS, but noted that communication with drivers, AVL and managers in field helps the agency "keep on top [of weather conditions] and make changes as needed."
Pennsylvania 6	Field staff discuss all forecasts to determine the response to a weather event. Decisions are based on experience, forecasts and precipitation types.
Pennsylvania 8	Checking roads and conditions in person.
Pennsylvania 9	Input from maintenance personnel with years of winter maintenance experience.
Washington 3	It depends on the weather forecast, whether abrasives are needed for freezing rain, liquid for dry frosty mornings, or a snowplow with a slurry applied for snowstorms.
Wyoming 2	Past experience with the type of storms.

Real-Time Adjustments to Maintenance Actions

During storm events, maintenance supervisors may need to adjust their directions to crews based on real-time pavement temperature data from truck sensors transmitted automatically by AVL or sensor systems on DOT vehicles. Table 30 identifies the frequency with which field personnel indicated that their agencies' maintenance supervisors make these adjustments.

Table 30. Frequency of Real-Time Adjustments to Maintenance Actions

Frequency	# of Respondents	% of Respondents
Every Storm Event	9	15.00
About Half of Storm Events	8	13.33
Usually	13	21.67
Seldom	13	21.67
Never	7	11.67
Not Sure/Don't Know	3	5.00
Not Applicable	7	11.67

Table 31 provides additional details respondents offered about the decisions maintenance supervisors make when real-time weather data redirects maintenance actions in the field.

Table 31. Comments About Real-Time Adjustments to Maintenance Actions

State/Respondent	Comments
Colorado	Buy-in on mobile data is not consistent statewide, but the agency has seen a more efficient use of deicer materials in areas that consistently use mobile friction data.
Delaware 1	The agency does use real-time systems but they are not located on trucks.
Delaware 3	The agency uses weather sensors, RWIS, traffic cameras and field reports to change its response throughout a storm. This includes salting operations, level of service (how many roads the agency tries to maintain), going to "plow only," when to have crews sleep, when to use liquid applications, and other practices.
Idaho 2	While the agency does not have real-time data, the respondent recognizes its benefits.
Indiana 5	The agency has installed MARWIS units on a few trucks in the Greenfield districts. Managers monitoring these systems "will look at the bread crumbs and make some determinations based on what they are seeing."
Indiana 7	A mix of RWIS and MARWIS data is used to evaluate conditions and make adjustments in real time.
Indiana 10	Road and vehicle sensors provide an accurate look at treatment effectiveness on specific routes and how weather affects those routes.
Massachusetts	Approximately three unspecified units are scheduled to be installed before this season in the respondent's district.

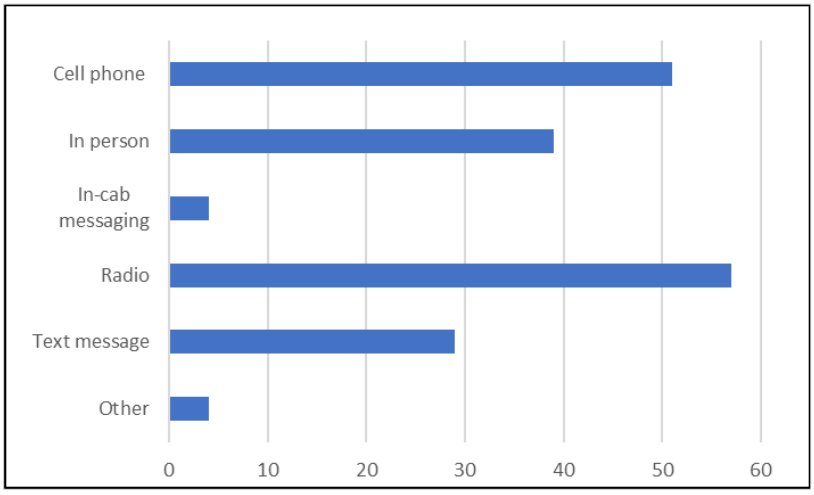
State/Respondent	Comments
Nevada 1	Operators do not currently transmit usable data from the trucks, but operators use truck road and air temperature gauges to aid decision-making.
Nevada 3	A few plows are equipped with sensors, but the agency's current system isn't deemed reliable enough to inform decision-making.
New York 2	The respondent noted that "we are constantly monitoring storm and weather conditions using both in-truck monitors and feedback from Verizon Fleet which can show traffic flow. We use surface temperature data to adjust our salt application rates."
New York 3	Supervisors adjust salt application rate and use of chemical deicing agents depending on road temperature and predicted temperatures.
Ohio 1	Generally data is shared with drivers and they make individual adjustments instead of the agency issuing overarching directive changes.
Ohio 3	The agency's trucks have a camera, GPS locator and sensors tied to hydraulics systems. Managers can use the system to view truck locations, and if trucks are spreading material, they can see the roadway. Treatment plans can be adjusted given what is seen in real time.
Pennsylvania 4	AVL, RWIS, communication with field personnel and in-field views contribute to changes in decision-making as conditions dictate.
Pennsylvania 5	Truck operators report conditions and temperatures to their foremen. Decisions are made between foremen and management on any changes that might be needed due to conditions.
Pennsylvania 6	Operators are trained to utilize the information on their temperature sensors. For the most part, a supervisor in the field monitoring real-time conditions provides direction.
South Dakota 1	As conditions change, recommendations change. Final decisions are left with the plow drivers.
South Dakota 3	MDSS will indicate forecast changes, which in turn require recommendation changes.
South Dakota 4	Road and weather information available through the agency's MDC units and WebMDSS guidance is constantly monitored through every storm.
Utah	The agency uses RWIS data rather than mobile sensors.
Wyoming 2	When information comes in as temperatures rise or start to drop, the types of materials used and amounts are adjusted where needed.

3.5 Managing Weather Information

Conveying Weather Information

Communication between maintenance supervisors and operators in the field is critical to effectively address rapidly changing weather conditions. Cell phones and truck radio are the primary means of communications between supervisors and field operators. Other common methods are in-person discussion and text messages. Both supervisors and field personnel use cell phones and radios most frequently to communicate with each other. Figure 5 summarizes survey responses.

Figure 5. Communication Methods: Supervisors to Field Operators

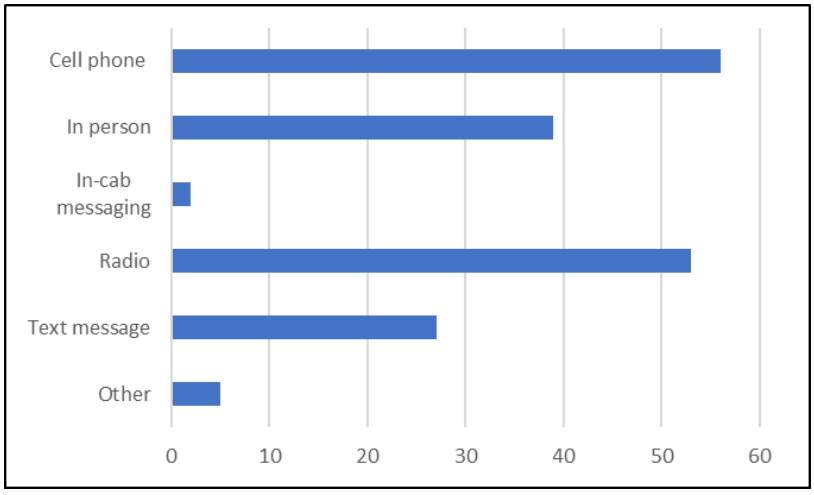


A few respondents commented on other ways weather information is communicated to operators in the field:

- Email (Massachusetts, Pennsylvania 4).
- Email is used by supervisors to keep higher-level management aware of real-time conditions and incidents (for example, road closures) during the course of an event. Information is usually conveyed to operators in person or by radio (New York 2).
- Drivers talk to one another (Pennsylvania 4).
- Meteorologists are available 24/7 year-round (Utah).

Field operators overwhelmingly use cell phone (audio calls) and radio to convey road condition information back to the central office, while supervisors use a slightly broader range of methods. Figure 6 summarizes survey responses.

Figure 6. Communication Methods: Field Operators to Supervisors



A few respondents commented on operator practices for sharing weather information with central office staff:

- Calls are made through the chain of command (Massachusetts).
- Supervisors and lead workers are the only employees issued state cell phones (Nevada 1).
- Radio communication is made to an operations center (Nevada 2).
- Email is used at times (New York 3).
- Managers in the field will most likely make calls while on their field views; foremen checking routes also make that call (Pennsylvania 4).

Improving Acquisition and Use of Weather Information

Both respondent groups were asked to identify the most important changes their agencies could make to improve how weather information is acquired, used and translated into road maintenance actions by selecting from among a range of actions or practices.

Additional and better training in understanding and applying weather information were two areas most respondents from both groups reported as likely to improve use of weather data for winter road maintenance. More frequent interaction with meteorologists is also recommended by many respondents. Both groups concurred that developing closer ties to federal programs and partnering with nearby agencies would be beneficial. Figure 7 summarizes field personnel survey responses.

Figure 7. Changes to Improve Acquisition and Use of Weather Information

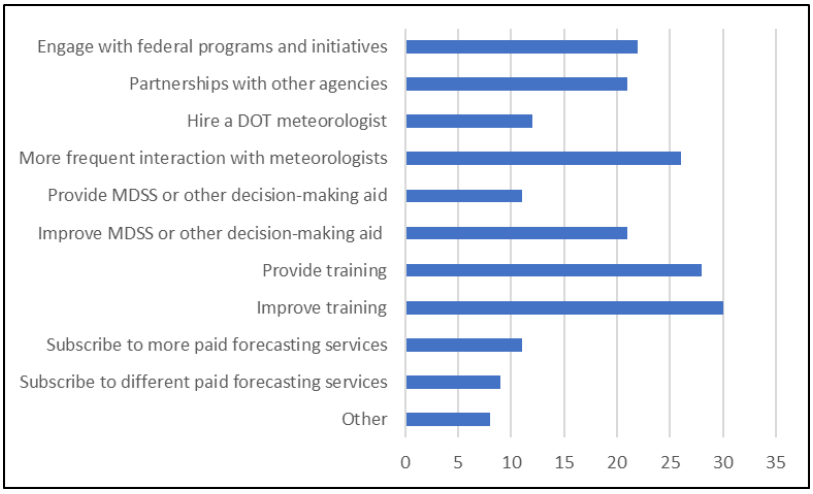


Table 32 provides respondents' additional comments about improving their agencies' acquisition and use of weather information.

Table 32. Comments About Improving Acquisition and Use of Weather Information

State/Respondent	Comments
Indiana 9	The agency is currently working on making effective use of available technology.
Kansas 1	Supervisors are urged, as time permits, to communicate more frequently with a paid forecast service.
Kansas 2	Forecasts will never be exact so constant monitoring of information is necessary.

State/Respondent	Comments
Nevada 1	The respondent reported "a good relationship with the local NWS." More RWIS stations are needed to gather more ground truth information for current forecasters to provide better forecasts.
Pennsylvania 1	The respondent recommends relying on the local news forecast for weather-related decisions instead of a paid forecast.
Pennsylvania 4	More is not always better. The respondent provided an example of five forecasts saying one thing and another saying something else. In these cases, the agency may feel it's necessary to use the forecast describing more severe outcomes.
Pennsylvania 6	More accurate forecasting by all meteorologists, especially more accurate storm totals, would be helpful. The agency provides all the tools needed to make the maintenance actions needed.
South Dakota 1	There isn't a one-size-fits-all approach to forecasts. Each supervisor needs to find a few different apps and sites that can inform maintenance decisions.

Challenges to Improving Weather Information Acquisition and Use

Many respondents indicated a desire to improve their agencies' acquisition and use of weather information, and identified the key impediments to making positive changes. Costs and funding were cited by many respondents identifying challenges; others noted challenges with managing data and technology-related needs or deficiencies. Table 33 summarizes survey responses.

Table 33. Challenges to Improving Weather Information Acquisition and Use

Issue/Challenge	State/Respondent	Description
Accuracy	Pennsylvania 9	The accuracy of forecast and the risk involved.
Costs and Funding	Delaware 1, Idaho 2, Indiana 9, Massachusetts, Nevada 2, Ohio 2, Ohio 4, Pennsylvania 5, Texas, Washington 1, 2 and 3, Wyoming 2	*Delaware 1*. Funding. A light winter last year generated no political will to improve the agency's response. *Idaho 2*. The respondent indicated interest in a "live feed into the trucks," but noted that "the thing that gets into the way is funding." *Nevada 2*. Budgeting to pay for detailed road weather information. *Texas*. The primary roadblock is that the cost of a paid forecasting service needs to be justified. The respondent noted that the agency "has been very successful in our weather response utilizing the existing resources we have access to." *Wyoming 2*. Budget constraints.
Data Management	Kansas 2, New York 8, Pennsylvania 1, Utah, Wyoming 1	*Kansas 2*. There are many sources available and most provide the same information. The respondent noted that "you could spend a fortune in budget trying to get this information." A good local source and dedicated monitoring of updated information are the best practices for decision-making. *New York 8*. The agency examines post-storm severity analytics. *Pennsylvania 1*. Currently operators are called out according to the paid forecast but should use the local forecasts.

Issue/Challenge	State/Respondent	Description
		Utah. More current road weather information is needed. RWIS is a spot assessment, and connected vehicle data can fill the gaps. The respondent noted that radar coverage is very poor in Utah. The Utah respondent also said this: *I think it is important that those in operations use a road weather forecast and don't confuse themselves with free public weather forecasts. There is a significant difference between the two. A DOT meteorologist can really facilitate this effort.* *Wyoming 1*. In-house forecasting tends to focus on interstates or adjacent routes.
Functionality	Indiana 9	User-friendly interfaces, functionality and accountability are important.
Obtaining Buy-In	Colorado	Buy-in from all maintenance personnel is needed.
Resistance to Change	Pennsylvania 5, South Dakota 3 and 4	*Pennsylvania 5*. Ingrained habits. *South Dakota 3*. Historic ways of doing things. An example of this is those who are against anti-icing. *South Dakota 4*. The agency's biggest issue is "getting employees to buy in to using the devices to their best potential. Many get caught up in doing things the same old way they always have and resent the technology that could help them."
Technology	Indiana 8, Nevada 1, Ohio 4, Pennsylvania 4, Pennsylvania 8, Wyoming 2	*Indiana 8*. The agency is constantly improving its acquisition and use of weather information. Currently, the agency is adding AVLs to its snow fleet, which should greatly improve operations. *Nevada 1*. Information is utilized efficiently. The respondent recommended focusing on improving radar resolution with help from partner agencies and installing many more RWIS stations to help forecasters fine-tune area forecasts. *Ohio 4*. Area for improvement: Trucks outfitted with real-time weather maps. *Pennsylvania 4*. More RWIS and updating all AVLs. *Pennsylvania 8*. Permission to use outside websites. *Wyoming 2*. The respondent looks forward to the availability of tablets so radar and weather information can be used in department vehicles.
Training	Colorado, Pennsylvania 8, South Dakota 1, South Dakota 2	*Colorado*. Training needs to keep pace with new technology and forecast products. *South Dakota 1*. More training for supervisors on how to understand weather patterns and forecasts and to learn the weather in their area. Once a supervisor has more experience with weather patterns in a specific area, better decisions are made. *South Dakota 2*. More hands-on training with MDC operators.

4 Literature Search

A literature search of recent publicly available resources identified publications and resources that are organized into the following topic areas:

- Previous Clear Roads Research
- National Research and Guidance
- State and Local Agency Resources

4.1 Previous Clear Roads Research

Mobile Technologies for Assessment of Winter Road Conditions, CR16-03, SRF Consulting Group Inc., Clear Roads Pooled Fund, March 2019.
https://clearroads.org/wp-content/uploads/dlm_uploads/FR_CR.16-03_7.22.19.pdf
From the abstract: Mobile RWIS technologies are still relatively new to the market, with only a few early-adopting agencies deploying them, primarily in testing situations. This study provides a comprehensive and comparative analysis of four commercially available mobile RWIS sensors. The sensors in the study include: Lufft's MARWIS, Teconer's RCM411, High Sierra's Mobile IceSight, and Vaisala's DSP310.
….
The study compared the sensors' performance while measuring air temperature, surface temperature, relative humidity, surface condition, water film thickness, and friction. The evaluation also compared qualitative aspects of the sensors such as installation methods. The project found that overall, sensors performed similarly across all parameters. This report ranks sensors by accuracy, but the absolute differences in values used to determine rank are often very small. The study also developed standardized recommendations for various mobile sensor parameters. While differences across sensors and the high variability in their readings make establishing universal standards difficult, some commonalties were found. The report includes a suggested matrix of a few basic levels categorizing grip, surface state, and mobility impact.

Accumulated Winter Season Severity Index (AWSSI) Enhancements in Support of Winter Road Maintenance, CR16-02, Midwestern Regional Climate Center, Clear Roads Pooled Fund, February 2019.
https://clearroads.org/project/16-02/
From the project summary: The project's goal was to enhance the MRCC's Accumulated Winter Season Severity Index (AWSSI) tool with data from additional locations and added functionality.

The project had four tasks:

1: Add at least one additional AWSSI location to each Clear Roads state.

2: Add the ability to overlay past years on the current-year AWSSI time-series plot.

3: Display projected information for the remainder of the winter season.

4: Determine the feasibility of an augmented "Road AWSSI" tool.

Mapping Weather Severity Zones, CR10-02, John J. Mewes, Clear Roads Pooled Fund Study, September 2012.
http://clearroads.org/wp-content/uploads/dlm_uploads/MappingWeatherSeverityZones-FinalReport.pdf
From the abstract: The goals of this project were to develop a methodology to map winter severity from a winter maintenance perspective, and to create electronic maps and associated geospatial data

depicting winter weather severity across the country. … Four significant component measures of winter severity were selected for mapping during the project. These measures included average annual snowfall amounts and average annual duration of each of snowfall, freezing rain, and blowing/drifting snow. … In addition to maps of these component winter severity measures, a composite map illustrating an overall winter severity index was also developed through mathematical combination of the component measure data. Geospatial representations of the data, in the form of ESRI shapefiles, were also developed and provided for each of the component datasets as well as the overall winter severity index.

4.2 National Research and Guidance

Statewide Road Weather Condition Web Sites, Road Weather Management Program, Federal Highway Administration, February 2020.
https://ops.fhwa.dot.gov/weather/resources/links.htm
This web page list includes 48 websites from 40 states that provide road weather information. Also included are government websites and those of weather-related associations and programs.

2019 Road Weather Management Performance Measures Update, Deepak Gopalakrishna and Taylor Gestwick, Federal Highway Administration, September 2019.
https://ops.fhwa.dot.gov/publications/fhwahop19089/fhwahop19089.pdf
From the abstract:

> The Federal Highway Administration's Road Weather Management Program (RWMP) assesses its progress toward meeting programmatic objectives through established performance measures. Assessments have been completed and documented in 2009, 2012, 2015, and 2017, and this update is the next iteration of this periodic review. This report provides a concise evaluation of the RWMP's progress and success by mapping the performance measures to at least one of the following categories: (1) road weather management impacts, (2) application of road weather management tools and technologies, (3) road weather management capacity building, and (4) partnerships and stakeholder collaboration. Overall, the 2019 report presents the latest results of the RWMP's performance measures, highlights significant changes or improvements from the last update, and lists recommendations on future focus areas for the RWMP. The report also serves as a resource and outreach product to further advance the importance and widespread implementation of road weather technologies.

The report includes two appendices:

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

"FHWA Road Weather Program and TSMO365," Roemer Alfelor, FHWA Office of Operations, *2018 AASHTO MaC Meeting—Maintenance Operations Technical Working Group*, June 2019.
https://transops.s3.amazonaws.com/uploaded_files/NOCoE%20RWM%20Peer%20Exchange%20-%20FHWA%20Weather%20Program.pdf
This presentation provides an overview of FHWA's Road Weather Program and the 2019 AASHTO TSMO (Transportation Systems Management and Operations) Community of Practice for Road Weather Management.

Weather-Savvy Roads: Resources to Aid Implementation, Federal Highway Administration, 2019.
https://ops.fhwa.dot.gov/publications/fhwahop19002/fhwahop19002.pdf
From the document: The Weather-Savvy Roads (WSR) initiative promotes deployment of two distinct road weather management solutions that enable transportation agencies to be proactive in managing the surface transportation system ahead of and during adverse weather events. It is being conducted under the fourth round of Every Day Counts (EDC-4). Hosted on the Federal Highway Administration (FHWA) Road Weather Management Exchange, the WSR Resource Toolkit provides information to practitioners looking to learn more about what is needed to successfully adopt WSR's two distinct road weather management solutions: Pathfinder and Integrating Mobile Observations (IMO). Located at https://go.usa.gov/xnSqy, users will find promotional publications, videos, case studies, fact sheets, and more.

Related Resource:

> **Pathfinder Overview**, On-Ramp to Innovation: Evert Day Counts, Federal Highway Administration, undated.
> https://ops.fhwa.dot.gov/publications/fhwahop18034/fhwahop18034.pdf
> *From the publication*: Pathfinder, a collaborative strategy for proactive transportation system management ahead of and during adverse weather events, encourages State departments of transportation (DOTs), NWS and weather service contractors to share and translate weather forecasts and road conditions into consistent transportation impact messages for the public.

Meteorological Assimilation Data Ingest System (MADIS), National Oceanic and Atmospheric Administration, National Weather Service, last updated July 25, 2018.
https://madis.ncep.noaa.gov/index.shtml
From the website: MADIS is a meteorological observational database and data delivery system that provides observations that cover the globe. MADIS ingests data from NOAA data sources and non-NOAA providers, decodes the data then encodes all of the observational data into a common format with uniform observational units and time stamps. Quality checks are conducted and the integrated data sets are stored along with a series of flags indicating the results of the various QC checks. MADIS provides several methods for users to access the data to meet their needs. Users can request data from July of 2001, which is when MADIS was first available to the public, to the present.

Connected Vehicle-Enabled Weather Responsive Traffic Management, Deepak Gopalakrishna, Fred Kitchener, Nayel Urena Serulla, Michelle Neuner, Joe Schmidt, Gene Donaldson and Jennifer Duvall, U.S. Department of Transportation, April 2018.
https://rosap.ntl.bts.gov/view/dot/35625
From the abstract: Weather Responsive Traffic Management (WRTM) is an initiative under the Federal Highway Administration's (FHWA) Road Weather Management Program that supports traffic management agencies and professionals in implementing effective advisory, control, and treatment strategies to mitigate transportation challenges due to adverse weather. Effective deployment of WRTM strategies depends upon an agency's ability to collect and integrate traffic, weather, and road condition data to effectively analyze the impacts of weather conditions and deliver pertinent information back to the travelers.
….
This document summarizes the work completed to strengthen the linkages between WRTM and connected vehicle (CV) technology. It also summarizes the guidance developed under this task to help State DOTs integrate the emerging CV technology with their road weather management practices.

Related Resource:

> **Connected Vehicle-Enabled Weather Responsive Traffic Management: The Next Generation of Weather Responsive Traffic Management**, Road Weather Management, Federal Highway Administration, April 2018.
> https://rosap.ntl.bts.gov/view/dot/36794
> This four-page fact sheet summarizes the technology of Connected Vehicle-Enabled Weather Responsive Traffic Management.

Road Weather Management Benefit Cost Analysis Compendium, Michael Lawrence, Paul Nguyen, Jonathan Skolnick and Mathies Wahner, Federal Highway Administration, April 2017.
https://ops.fhwa.dot.gov/publications/fhwahop16093/fhwahop16093.pdf
From the abstract:

> The Road Weather Management (RWM) Benefit Cost Analysis (BCA) Compendium provides information about benefit cost analyses conducted around the country for specific RWM technologies or operational strategies. The actual project evaluations involve the use of custom spreadsheets developed by the agency or its contractors, or the application of available software tools to the BCA. The Compendium also includes hypothetical cases designed to demonstrate how BCA can be used for a specific RWM technology or operational strategy. FHWA has developed a sketch planning BCA tool —the Tool for Operations Benefit/Cost (TOPS-BC)—for application to TSMO projects, including RWM projects. For the hypothetical cases, TOPS-BC is used to assist in the measurement of benefits and costs and in the calculation of the benefit cost ratio. Each case demonstrates how planners conducted, or could conduct, a BCA on one or more RWM technologies or strategies. There are 27 cases studies presented in the RWM Compendium, and each addresses one or more specific BCA concepts or procedures. Note that the hypothetical BCA case studies and scenarios included in this compendium for several road weather management strategies, including Connected Vehicle applications, utilize assumptions on costs and benefits that do not reflect actual costs and benefits associated with those strategies and are presented only for demonstration purposes.

Case studies for surveillance, monitoring and prediction include:

- Case Study 4.1: Michigan Department of Transportation Regional Road Weather Management Systems Pre-Deployment Studies (page 46 of the report, page 68 of the PDF).
- Case Study 4.2: The Utah Department of Transportation Weather Operations/Road Weather Management Information System Program (page 49 of the report, page 71 of the PDF).
- Case Study 4.4: Road Weather Information System Deployment in Idaho (page 58 of the report, page 80 of the PDF).

Case studies for decision support, control and treatment include Case Study 6.5: Road Condition Reporting Application in Wyoming (page 116 of the report, page 138 of the PDF).

Case studies for weather response or treatment include Case Study 7.1: Maintenance Decision Support System Implementation: The City and County of Denver (page 136 of the report, page 158 of the PDF).

Pikalert System Vehicle Data Translator (VDT) Utilizing Integrated Mobile Observations: Pikalert VDT Enhancements, Operations and Maintenance, Brenda Boyce, Gerry Weiner, Amanda Anderson and Seth Linden, Intelligent Transportation Systems Joint Program, U.S. Department of Transportation, March 2017.
https://rosap.ntl.bts.gov/view/dot/34719
From the abstract: The Pikalert System provides high precision road weather guidance. It assesses current weather and road conditions based on observations from connected vehicles, road weather information stations, radar, and weather model analysis fields. It also forecasts future weather and road conditions out to 72 hours utilizing information from numerical weather models. As connected vehicle observations become more and more prevalent with the advent of autonomous vehicles, Pikalert has been designed to utilize these observations effectively. In particular, a number of quality check algorithms have been incorporated to guarantee that erroneous observations are flagged and eliminated. Pikalert then assembles the observations that have passed the quality checks, associates them with the appropriate road segments, and then uses them in assessing the road segment weather conditions. Detailed reports can then be generated characterizing the status of the various road segments assuming there is adequate connected vehicle coverage. Pikalert advises users of the presence of three conditions (precipitation, road surface, and visibility) and will make pavement treatment recommendations for snow and ice removal. Pikalert recommendations are made available through web-based technology that supports browser-based displays and smartphones. The software for the Pikalert System can be downloaded from the Open Source Application Development Portal (OSADP) at www.itsforge.net. Download the files associated with Pikalert-5.0, which includes the code, instructions, libraries, and sample files. The Pikalert System is a licensed open source distribution. For the good of the road weather community, any changes made to the software, particularly the algorithms, we request that any changes be deployed to the OSADP for others to use.

Collaboration Across the Road Weather Enterprise: The Pathfinder Project, Megan Helsel, Brenda Boyce, Tyler Poling and Sudharson Sundararajan, Federal Highway Administration, December 2016.
https://ops.fhwa.dot.gov/publications/fhwahop16086/fhwahop16086.pdf
From the abstract: Weather has a significant impact on the operations of the nation's roadway system year-round. To help improve weather impacts on our roadways the Federal Highway Administration (FHWA) Road Weather Management Program (RWMP) and the National Oceanic and Atmospheric Administration's (NOAA's) National Weather Service (NWS) have been working together to document the state-of-the-practice and working relationships between State Departments of Transportation (DOTs) and the weather enterprise. The Pathfinder project was initiated to document current State DOT interactions and working relationships with the weather enterprise (both NWS and private sector). The team documented best practices across the agencies to disseminate consistent messages about the weather and its impact on the roads. This document serves as a guidance document for improving the collaboration between State DOTs and the weather enterprise.

Best Practices for Road Condition Reporting Systems: Synthesis Report, Dean Deeter, Ginny Crowson, Tina Roelofs, Jeremy Schroeder and Deepak Gopalakrishna, Federal Highway Administration, September 2014.
https://rosap.ntl.bts.gov/view/dot/41098
From the abstract: Often, the center of an agency's traveler information system is a Road Condition Reporting System (RCRS). The RCRS is frequently the focal point, populated by manual and automated data and information feeds, supplying information to various information dissemination mechanisms. While the potential benefits of an RCRS are obvious, there are also costs of associated with the development, management, and support of the software system as well as costs associated with the

operator time to perform entry. The benefits and costs are impacted by many institutional and technical issues that operations managers must face. This report presents a synthesis of current industry practices regarding the design, development, operation, maintenance, and use of RCRSs.

Best Practices for Road Weather Management, Version 3.0, Ray Murphy, Ryan Swick and Gabe Guevara, Office of Transportation Operations, Federal Highway Administration, June 2012.
https://ops.fhwa.dot.gov/publications/fhwahop12046/fhwahop12046.pdf
From the abstract: This report contains 27 case studies of systems in 22 states that improve roadway operations under inclement weather conditions. Each case study has six sections including a general description of the system, system components, operational procedures, resulting transportation outcomes, implementation issues, as well as contact information and references.

4.3 State and Local Agency Resources

The publications below are a sampling of agency efforts to collect winter weather and road data and apply it to winter road management.

Multiple Agencies

RWIS Network Planning: Optimal Density and Location, Tae J. Kwon and Liping Fu, Aurora Program Pooled Fund Study and Federal Highway Administration, June 2016.
http://publications.iowa.gov/27266/1/Final%20Report_RWIS_network_planning_for_optimal_density_and_location_w_cvr.pdf
From the abstract: This project developed several approaches for determining the optimal location and density of RWIS stations over a regional highway network. To optimize locations, three approaches were developed: surrogate measure–based, cost-benefit–based, and spatial inference–based. The surrogate measure–based method prioritizes locations that have the highest exposure to severe weather and traffic. The cost-benefit–based method explicitly accounts for the potential benefits of an RWIS network in terms of reduced collisions and maintenance costs. The spatial inference–based method maximizes the use of RWIS information to optimize the configuration of an RWIS network. To optimize network density, a cost-benefit–based method and a spatial inference–based method were developed.

To demonstrate the applications of the proposed approaches and evaluate existing RWIS networks, four case studies were conducted using data from one Canadian province (Ontario) and three US states (Minnesota, Iowa, and Utah). It was found that all approaches can be conveniently implemented for real-world applications. The approaches provide alternative ways of incorporating key road weather, traffic, and maintenance factors to optimize the locations and density of RWIS stations in a region; the alternative to use can be decided based on the data and resources available.

California

WeatherShare—Phase V: Caltrans Enterprise Implementation, Research Notes, Caltrans Division of Research Innovation and System Information, Caltrans, June 2019.
https://dot.ca.gov/-/media/dot-media/programs/research-innovation-system-information/documents/research-notes/task3266-rns-6-19v2-a11y.pdf
From the document: WeatherShare is to become the central repository for Caltrans RWIS data and weather information. Caltrans maintenance and operations personnel will have access to real-time and

historical weather information that will help them manage roadways, apply treatments, and handle weather-related incidents more effectively.

This platform of weather observations and forecasts with near real-time road sensor data will allow Caltrans crews to make the best possible decisions for both maintenance operations and incident response.

Related Resources:

WeatherShare, Western States Rural Transportation Consortium, last updated 2016.
http://www.westernstates.org/Projects/Weathershare/Default.html
From the website: WeatherShare was developed by the Western Transportation Institute at Montana State University, and sponsored by the California Department of Transportation to improve weather related situation assessment, incident recognition, and response by providing streamlined access to surface weather data from multiple sources.

The Phase II system covers all of California with emphasis on its more than 16,600 miles of state and federal highways and provides the most recent and forecasted weather information. The information is collected from over 3,200 surface weather stations from state and National weather sources such as Caltrans Road Weather Information Systems (RWIS), California Data Exchange Center (CDEC), MesoWest, NOAA's Meteorological Assimilation Data Ingest System (MADIS) and the NOAA National Digital Forecast Database (NDFD). Three-level Quality Control (QC) procedures have been implemented to flag questionable sensor readings. Other value-added features include mapping NDFD data to California highway mileposts, and using combinations of data to detect and display alert conditions.

In Phase 3, WeatherShare will become Caltrans' repository for Caltrans RWIS data. As such, it will focus more on the needs of Caltrans personnel. Another Caltrans project, the One Stop Shop, has stepped in to provide travelers with important road and weather information. This division of roles will allow the two systems to better focus on the diverse needs of both travelers and maintenance teams.

Colorado

Weather-Savvy Roads: Colorado's Pathfinder Process, *Pathfinder Case Study*, On-Ramp to Innovation: Evert Day Counts, Federal Highway Administration, 2018.
https://ops.fhwa.dot.gov/publications/fhwahop18028/fhwahop18028.pdf
From the background: The Colorado Department of Transportation (CDOT) has always maintained a good working relationship with the weather forecasting community. The National Weather Service (NWS) has three forecast offices throughout Colorado—Boulder, Pueblo, and Grand Junction—that work together to formulate a statewide view of weather conditions. CDOT contracts with a private road weather forecaster, Iteris, Inc., to provide road condition forecasts during major weather events. The emergence of Pathfinder gave CDOT the opportunity to strengthen its relationships with the weather forecasting community and determine the impact that weather events have on State highways and interstates, and to ensure that travelers receive consistent messages regarding travel conditions.

Idaho

Idaho TC Winter Maintenance Performance System, Best Practices for Road Weather Management, Road Weather Management Program, Version 3.0, Federal Highway Administration, June 2012.
https://ops.fhwa.dot.gov/publications/fhwahop12046/fhwahop12046.pdf
From page 32 of the publication, page 38 of the PDF:

> The Idaho Transportation Department (ITD) is in the final stages of developing its Winter Maintenance Performance Measures System which will include 87 Road Weather Information System (RWIS) sites. At the time of publication, sixty sites are operational. Statewide implementation of the system began in 2011. Currently, ITD is identifying the performance levels of its winter maintenance operations in all districts. Depending on the results of this effort, some existing maintenance practices in various locations may be altered to increase operational efficiencies. ITD anticipates there will be several seasons of continual improvements in the RWIS network while allowing time for appropriate operational adjustments to be made.

Illinois

Getting Around Illinois, Illinois Department of Transportation, undated.
http://www.gettingaroundillinois.com
*From the website***:** Getting Around Illinois is a web-based interactive mapping site that provides the ability to search and display several sources of transportation data. You can find information on winter road conditions, annual average daily traffic, road construction, trucking routes, and planned road projects.

Iowa

Iowa Environmental Mesonet, Iowa State University, 2020.
https://mesonet.agron.iastate.edu
From the website: The Iowa Environmental Mesonet (IEM) collects environmental data from cooperating members with observing networks. The data are stored and made available on this website.

WeatherView: Iowa DOT Open Data, Iowa Department of Transportation, last updated June 2019.
https://data.iowadot.gov/datasets/01c86f1c7ff0473cb12f714b512d573f
WeatherView is Iowa DOT's map for displaying AWOS and RWIS Data.

Michigan

MDOT's Road Weather Information System, Michigan Department of Transportation, 2020.
https://www.michigan.gov/mdot/0,4616,7-151-9615-253230--,00.html
From the website: Using federal grant funding, MDOT began installing a new system to monitor atmospheric and road surface conditions in an effort to better manage winter maintenance activities and to provide more travel information to motorists. The concept isn't new (several other Midwestern states have similar systems), but it's relatively new to Michigan.

The system is made up of a network of Environmental Sensor Stations, or ESSs. These stations (the towers you're seeing) combine several types of sensors to measure air and road surface temperatures, barometric pressure, wind, salt concentrations on the road surface, frost depth and dewpoint, as well as cameras to verify conditions at the site. Using the data collected from the 68 existing stations

installed since 2008, MDOT and the contract county road commissions providing maintenance services are able to better predict when ice will begin to form on the roadway or bridge decks, or see when snow is blowing and drifting across the road, improving efficiency in those operations. The department is adding 7 more stations this year in the northern Lower Peninsula.

Minnesota

"Location Optimization of Road Weather Information System (RWIS) Network Considering the Needs of Winter Road Maintenance and the Traveling Public," Tae J. Kwon, Liping Fu and Stephanie J. Melles, *Computer-Aided Civil and Infrastructure Engineering*, Vol. 32, Issue, 1, pages 57-71, January 2017. Citation at https://onlinelibrary.wiley.com/doi/abs/10.1111/mice.12222
From the abstract: This study presents an innovative approach to the planning of a critical highway sensor infrastructure—road weather information system (RWIS). The problem is formulated to minimize the spatially averaged kriging variance of hazardous road surface conditions while maximizing the coverage of accident-prone areas. This optimization framework takes explicit account of the value of information from an RWIS network, providing the potential to enhance the overall efficacy of winter maintenance operations and the safety of the travelers. Spatial simulated annealing is used to solve the resulting optimization problem and its performance is demonstrated using a real-world case study from Minnesota, United States. The case study illustrates the distinct features of the proposed model, assesses the effectiveness of the current location setting, and recommends additional stations locations. The findings of our study suggest that the proposed model could become a valuable decision-support tool for planning a new RWIS network and evaluating the performance of alternative RWIS expansion plans.

Nebraska

"NDOT's Message to Motorists: 'Your Safe Travel is Our Business'," Linda Wilson, *The Roadrunner*, Nebraska Department of Transportation, Winter 2019.
https://dot.nebraska.gov/media/12838/winter-2019.pdf
This online newsletter includes information about the agency's partnership with FHWA's Pathfinder project, a strategy for proactive road management before and during adverse weather. *From page 7***:**

> This is a collaborative effort between the Federal Highway Administration (FHWA), National Weather Service (NWS) and weather service contractors to share and translate weather forecasts and road conditions into consistent transportation impact messages for the public.
>
> After a successful Pathfinder Pilot project last fall, led by Jessica Sherwood, State Operations Center (SOC) Manager, and Jesse Schulz, SOC Meteorologist, NDOT expanded the effort statewide. Information is shared through NDOT's twitter feeds, other social media platforms and DMS message boards. A NWS online chat room is available for anyone to quickly ask questions and share weather-related information. NDOT districts utilize the Pathfinder chat room to closely monitor ever-changing weather forecasts, watches, advisories and warnings as a tool in preparing for potential storms. Pathfinder also aids driver decision-making and planning activities.

Utah

"UDOT Weather Program Traffic Operations Center," Jeff Williams, Utah Department of Transportation, *AASHTO Subcommittee on Transportation Systems Management and Operations Annual Meeting*, September 2017.
https://systemoperations.transportation.org/wp-content/uploads/sites/22/2017/05/Meteorologists-in-the-TMC.pdf
This meeting presentation describes why a transportation meteorologist is beneficial for a state agency, citing data indicating that the benefit-cost ratio of having a staff or contract transportation meteorologist is 11:1 based on winter maintenance cost savings. The presentation also notes that 89% of Utah DOT maintenance personnel changed maintenance approaches based on road weather forecasts. Also addressed are Utah DOT Pathfinder benefits of unified messages to change driver behavior, collaboration and resource sharing, multiple communications methods, and impact-based reporting.

Evaluation of the Utah DOT Weather Operations/RWIS Program on Traffic Operations, Zhirui Ye, Aurora Program Pooled Fund Study, November 2009.
https://westerntransportationinstitute.org/wp-content/uploads/2016/08/4W2324_UDOT_Phase_II_Report.pdf
From the abstract: The transportation community has been aware of the impacts of adverse weather on the roadway system and that the use of weather information can be beneficial in improving traffic operations. Many traffic management centers (TMCs) have integrated weather information into traffic operations. However, studies that provide comprehensive evaluations of how weather information will affect TMCs' operations have not been conducted. Thus, the main purpose of this study is to evaluate the impacts of weather information on TMC users through investigation of the Utah Department of Transportation's Weather Operations/RWIS Program.

Washington

Washington Weather, Washington State Department of Transportation, 2020.
https://www.wsdot.com/traffic/weather/default.aspx
This website offers drivers current conditions around the state, including mountain passes, live traffic maps, travel alerts, current weather, accessible traffic cameras throughout the state, and more.

WSDOT Road Weather Information Systems (RWIS) 9, Washington State Transportation Center, March 2018.
https://depts.washington.edu/trac/unpublished/wsdot-road-weather-information-systems-rwis-9/
From the website: In cooperation with and with support by WSDOT [Washington State DOT], researchers at the UW [University of Washington] have developed innovative, Web-based applications to provide current and forecast weather conditions for cross-state travel on state highways to WSDOT personnel and the traveling public. The resulting websites combine complex meteorological and roadway data from numerous sources and present them through user-friendly, intuitive Web interfaces. These websites have become extraordinarily popular among the citizens and businesses of Washington State, and during periods of adverse weather they play a crucial role in informing travelers crossing the mountain passes of delays and dangerous conditions. This project is continuing the complex work necessary to collect, process, maintain, and disseminate such a wide range of weather and roadway information.

Wyoming

Wyoming Department of Transportation (WYDOT) Road Condition Reporting Application for Weather Responsive Traffic Management, Federal Highway Administration, 2016.
https://rosap.ntl.bts.gov/view/dot/3576
From the publication: FHWA's Road Weather Management Program partnered with WYDOT [Wyoming DOT] to develop a new software application to improve the way maintenance personnel report road and weather conditions to their statewide Transportation Management Center (TMC), recommend variable speed limit (VSL) changes, and report a number of different traffic incidents including crashes and road hazards.

The primary goal of the WYDOT project was to improve maintenance staff road condition reporting. Specific objectives were to:

- Improve the efficiency of road condition reporting using a mobile application
- Improve the efficiency of the TMC operations in taking actions based on the reported road conditions
- Improve the timeliness of updated traveler information
- Improve the situational awareness of maintenance staff in the field regarding road weather conditions

Appendix A: Survey Questions

Two surveys were distributed to representatives of the 36 Clear Roads member agencies to gather information for this synthesis report: a survey for central office staff, and a second survey for selected field personnel. The two surveys included the same questions, with one exception—an additional section in the central office staff survey addressed the use of an in-house meteorologist.

The full text of survey responses, including contact information for respondents, is presented in a supplement to this report and available from the Clear Roads administrator.

Clear Roads Survey on Weather Forecasting Resources, Practices and Needs

Sources of Weather Information and Road Weather Conditions

* (Required) What sources of weather forecasts and conditions do your agency's maintenance supervisors use to decide when and where to mobilize crews for plowing, deicing, anti-icing and other winter maintenance activities? Please select all that apply.

- ASOS, AWOS (from FAA)
- Forecasts from local TV news
- In-house DOT meteorologist (staff or consultant)
- MADIS (from NOAA)
- National Weather Service
- Paid weather forecasting service such as AccuWeather or DTN (Please respond to **Question 1A** below.)
- Weather websites or apps (Please respond to **Question 1B** below.)
- Other (Please describe.)

1A. Please provide the name of the paid weather forecasting service and briefly describe it. Include in your description what the service provides, how staff at your agency interact with the service and its cost.

1B. Please provide the name of the weather websites or apps.

2. Does your agency participate in a partnership or coalition with other agencies or organizations for sharing weather forecasting information?
    - Not sure/don't know
    - No
    - Yes (Please describe the partnership or coalition.)

3. Which of the following sources of current road weather conditions are used by your agency's maintenance supervisors to supplement weather forecasts? Please select all that apply.
    - Data from mobile sensors on DOT vehicles (pavement temperature, etc.) transmitted automatically via AVL or similar system
    - Reports from plow drivers
    - Reports from the public (including social media posts)
    - RWIS station data
    - Video from traffic cameras
    - Visual assessment/looking out the window
    - None of the above
    - Other (Please describe.)

Note: The questions appearing under **Agency Weather Forecasting Personnel (Staff or Contract)** appeared only in the central office survey.

Agency Weather Forecasting Personnel (Staff or Contract)

* (Required) Does your agency have an in-house DOT meteorologist (staff employee or contractor/consultant)? (This does not include contracted weather forecasting services such as AccuWeather and DTN.)
  - Yes (Skips respondent to appropriate page.)
  - No (Skips respondent to appropriate page.)

Questions for Agencies With In-House Meteorologists

1. What is the employee/contract status of your agency's in-house meteorologist?
   - Full-time staff
   - Part-time staff
   - Contractor/consultant
   - Other (Please describe.)
2. How long has your agency had an in-house meteorologist, either on staff or through contract?
3. What is the annual cost of the in-house meteorologist to your agency?
4. How did your agency develop weather forecasts before hiring an in-house meteorologist?
5. What value/benefits does your agency receive from having an in-house meteorologist? Please select all that apply.
   - Cost-effective when compared to other practices
   - Greater confidence in forecasts from in-house meteorologist than from other sources
   - Increased access to a real person if we have questions (compared with paid forecast services)
   - In-house meteorologist can serve as liaison to emergency management/traffic management center
   - Targeted forecasts that focus on what matters to our agency
   - Other (Please describe.)

5A. Please use the space below to provide additional comments about the value and benefits your agency has identified.

Questions for Agencies Without In-House Meteorologists

1. What are your agency's reasons for not having an in-house meteorologist? Please select all that apply.
   - Cost is too high.
   - There is ample weather information already available to our agency from other sources.
   - We are pleased with our weather forecasting contractor.
   - We're uncertain about the benefits an in-house meteorologist would provide.
   - Other (Please describe.)

1A. Please use the space below to provide additional comments your agency's decision to not use an in-house meteorologist.

2. If your agency is considering hiring an in-house meteorologist in the future, what are your primary reasons for doing so? Please select all that apply.
   - Not applicable
   - Cost-effective when compared to other practices

- Greater confidence in forecasts from in-house meteorologist than from other sources
- Increased access to a real person if we have questions (compared with paid forecast services)
- In-house meteorologist can represent our agency to media, legislators, governor, etc.
- In-house meteorologist can serve as liaison to emergency management/traffic management center
- Targeted forecasts that focus on what matters to our agency
- Other (Please describe.)

Rating the Sources of Weather Information and Road Weather Conditions

1. Please indicate your agency's level of confidence in the weather forecasts and condition information your agency receives from each of the following sources using the rating scale of 1 = not at all confident to 5 = extremely confident. Include in your assessment recent past experiences as well as current sources of weather information.

(*Note*: Response options included "Don't know/haven't used" for each of the sources listed below.)

- ASOS, AWOS (from FAA)
- Forecasts from local TV news
- In-house DOT meteorologist (staff or consultant)
- MADIS (from NOAA)
- National Weather Service
- Paid weather forecasting service such as AccuWeather or DTN
- Weather websites or apps

1A. Please comment on and rate other significant sources of weather forecasts and condition information.

2. Are there any sources of weather information that your agency has tried but didn't find useful?
    - No
    - Yes (Please identify these sources and briefly describe why they weren't useful.)
3. Are there any sources of weather information that your agency doesn't use but that you'd like to try?
    - No
    - Yes (Please identify these sources.)

Translating Weather Information into Winter Maintenance Responses

1. In evaluating forecasts, how do your agency's maintenance supervisors manage uncertainty about forecast accuracy?
    - Compare forecasts from multiple sources
    - Contact DOT meteorologist for more information
    - Contact National Weather Service meteorologist or paid forecast service for more information
    - Contact neighboring jurisdictions for on-the-ground reports
    - Factor in previous accuracy of forecast source
    - Other (Please describe.)
2. How often do you or other staff at your agency interact with a meteorologist from any of the following sources?

(*Note*: For the rating question below, the online survey included five numbered options: 1 = never; 2 = occasionally; 3 = sometimes (during about half of storm events); 4 = often; and 5 = during every storm event. An N/A option was also included.)

- DOT meteorologist (in-house)
- National Weather Service meteorologist
- Paid weather forecast service
- Partnerships/coalition

2A. Please comment on your interactions with a meteorologist from another organization not identified in Question 2.

3. Please describe your interactions with a meteorologist from one or more of the organizations identified in Question 2. Include in your description the types of questions you ask and whether you typically get the information you need.

4. Which of the following tools or practices are used by your agency's maintenance supervisors to help decide what maintenance actions are needed for a specific weather forecast or conditions? Please check all that apply.
    - Decision tree or similar aid
    - Maintenance Decision Support System (MDSS)
    - Recommendations from crews currently in the field about what maintenance actions are needed
    - Recommendations from meteorologist about what actions are needed
    - Recommendations from other DOT staff about what actions are needed
    - None of the above
    - Other (Please describe.)

5. During storm events, how often do maintenance supervisors adjust their directions to crews based on real-time weather data from truck sensors transmitted automatically by AVL/sensor systems on DOT vehicles? (For example, directing crews to stop anti-icing based on pavement temperature data.)
    - Not applicable
    - Not sure/don't know
    - Never
    - Seldom
    - About half of storm events
    - Usually
    - Every storm event

5A. If your agency uses real-time data in this way, please briefly describe how it's used.

6. How do **maintenance supervisors** convey new or changing weather information—or revised maintenance directions based on new weather information—to operators in the field? Please select all that apply.
    - Cell phone (audio call)
    - In person, when operators return to garage
    - In-cab messaging system
    - Radio
    - Text message
    - Other (Please describe.)

7. If changing conditions in the field warrant a change in maintenance response (such as calling in more operators), how do **crews in the field** convey that information to the people responsible for making those decisions? Please select all that apply.
    - Cell phone (audio call)
    - In person, when operators return to garage
    - In-cab messaging system

- Radio
- Text message
- Other (Please describe.)

Assessing Agency Use of Weather Information

1. What are the most important changes your agency could make to improve how weather information is acquired, used and translated into road maintenance actions? Please select all that apply.
    - Create closer ties with federal programs and initiatives (e.g., Pathfinder, NWS, MADIS)
    - Create or improve partnerships with other nearby agencies for receiving weather forecasts
    - Hire a DOT meteorologist who can tailor weather forecasts to our needs
    - Interact more often with meteorologists that we have access to (through paid forecasting services, etc.)
    - Provide MDSS or other decision-making aids
    - Improve MDSS or other decision-making aids
    - Provide training on how to translate forecasts into maintenance actions
    - Improve training on how to translate forecasts into maintenance actions
    - Subscribe to **more** paid forecasting services
    - Subscribe to **different** paid forecasting services
    - Other change (Please describe.)
2. If you feel your agency has room to improve how it acquires and/or uses weather information, what are the main challenges or roadblocks preventing this from happening?

Wrap-Up

1. If available, please provide links to documents related to how your agency acquires weather information and uses it to make decisions about winter maintenance activities. Send any files not available online to sharon.vansluijs@ctcandassociates.com.
2. Please use this space to provide any comments or additional information about your previous responses.

research for winter highway maintenance

Lead state:

Minnesota Department of Transportation
Research Services
395 John Ireland Blvd.
St. Paul, MN 55155