Snow and Ice 2030

Synthesis Report

CLEAR ROADS

research for winter highway maintenance

CTC & Associates LLC

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16. Abstract

Changes in the snow and ice fighting industry are simultaneously challenging and promising. State departments of transportation (DOTs) continue to experience resource constraints and increasing driver shortages. As environmental changes create additional uncertainty, winter maintenance managers are striving to meet these challenges, find efficiencies and improve performance. A survey of winter maintenance professionals and review of relevant domestic literature gathered information to aid transportation agencies in exploring and implementing new practices and technologies. The survey received responses from 16 Clear Roads members and partners. These findings were supplemented with outreach to a small number of other winter maintenance experts. Respondents described new practices in six topic areas the Clear Roads Research Program uses to organize research and projects:

- Planning
- Equipment
- Materials
- Training
- Technology
- Safety

Respondents also identified emerging technologies of interest, including artificial intelligence and equipment to regulate salt use, and discussed barriers and challenges in implementing new practices. Recommendations and best practices for exploring and implementing new practices address collaboration and communication, internal and external education, and operational considerations.

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Executive Summary

As the snow and ice fighting industry changes, state departments of transportation (DOTs) continue to experience resource constraints and other challenges. Winter maintenance managers are striving to meet these challenges, find efficiencies and improve performance.

This synthesis project included a survey of winter maintenance professionals and review of relevant literature to aid transportation agencies in exploring new and emerging practices, procedures and equipment used in fighting snow and ice. The survey received responses from nearly 40% of the 39 Clear Roads members and a small number other winter maintenance experts who shared experiences and perspectives on the latest innovations, trends and hurdles in managing winter maintenance operations.

New and Emerging Snow and Ice Practices

Sixteen Clear Roads member and partner agencies and three winter maintenance experts identified more than 60 new and emerging practices used in snow and ice control. Practices are organized into six topic areas the Clear Roads Research Program uses to organize research and synthesis projects:

- Planning
- Equipment (including facilities)
- Materials
- Training
- Technology
- Safety (including outreach)

Some new practices could be categorized under more than one topic area. Final categorization considered how the respondent assessed the practice and the scope of the practice description in the context of other practices in that topic area.

The survey provided limited opportunities for respondents to describe in detail new practices in each topic area. For each topic area discussed below, the practices described by respondents are followed by additional practices identified but not described. Practices are summarized using common themes and the benefits and challenges cited by respondents.

Moving forward, most described practices have been successful enough for agencies to continue and most are transferable to other interested agencies. Practices respondents indicated were not likely to continue are highlighted in some topic areas.

Planning Practices

Eight respondents described new planning practices in winter maintenance.

Practice	Agency or Partner
Resource Management and Proper Material Usage	Colorado DOT
Performance Metric for Salt Use	Massachusetts DOT
Preemptive Interstate Closure	Nebraska DOT
Winter Severity Index Mapping	Nebraska DOT
Salt Use Goal	North Dakota DOT
Winter Severity Indices for Budget Planning	South Dakota DOT
Streamlining Route Logs and Tracking Materials Usage	Vermont Agency of Transportation (AOT)
Personnel and Equipment Resource Sharing	Wyoming DOT

The South Dakota DOT respondent identified but did not describe an additional planning practice: *Use of traffic speeds for operational decisions and post-storm performance analyses.*

Common Planning Themes

Common planning themes centered around two topic areas: managing resource use and weather severity measures.

Managing Resource Use. Three state DOTs reported new ways of managing salt use, while one focused on personnel and equipment resources:

- *Colorado* promotes understanding of material parameters with a deicer product guide, using friction data to inform salt use and inferring road conditions based on atmospheric data.
- *Massachusetts* developed a performance metric for salt use based on winter severity.
- *North Dakota* established a salt use goal measured by the ratio of salt use to liquid use in melting ice and snow.
- *Wyoming* districts share both personnel and equipment to manage snow and ice storms.

Weather Severity Measures. Two state DOTs described different uses for weather severity measures:

- *Nebraska* created a map providing visual indicators of forecasted winter weather severity to support managing operations.
- *South Dakota* applies a winter severity index to normalize historical expenditures and anticipate budget needs, replacing the traditional practice of using historical averages.

Practice Benefits and Challenges

Benefits of new planning practices include:

- More efficient operations and being prepared for winter events (*Colorado, Massachusetts, Nebraska, North Dakota* and *Wyoming*).
- Material and other savings (*Wyoming*) and decreased wear and tear on equipment (*Colorado*).
- Increased safety and/or decreased crashes (*Nebraska*).
- A systematic and logical method to analyze budget needs and communicate needs for winter-related supplies to decision-makers (*South Dakota*).

Challenges of new planning practices include:

- The need for constant training due to winter operator turnover (*Colorado*).
- Funding (*Colorado* and *North Dakota*).
- Correctly timing preemptive highway closures, providing parking areas for trucks impacted by the closure, and Google maps that direct traffic onto county roads (*Nebraska*).
- Classifying weather severity and the accuracy of forecasts (*Nebraska*).
- Managing logistics for every storm and quickly moving personnel and equipment based on storm forecasting (*Wyoming*).

Practices Unlikely to Continue

Vermont AOT's tested practice of streamlining route logs and tracking materials usage was unsuccessful. Similarly, *Nebraska DOT's* winter severity index mapping was not widely used and not likely to become standard practice.

Equipment and Facilities Practices

Fourteen respondents described 17 new practices associated with equipment and facilities.

Practice	**Agency or Partner**
Salt and Brine Practices: Brine-Making Equipment	Arizona DOT
Salt and Brine Practices: Brine Use in Conjunction with Mobile Sensors	Colorado DOT
Salt and Brine Practices: Brine-Making Equipment and Brine Use	Massachusetts DOT
Salt and Brine Practices: Brine-Making Facilities	Nebraska DOT
Salt and Brine Practices: Salt Storage Facilities	Texas DOT
Salt and Brine Practices: Brine-Making Equipment	Wyoming DOT
Grip Sensors: Mobile Friction Sensors	Colorado DOT
Grip Sensors: Road Surface Grip Sensors	Columbus, Ohio
Snowplow Blades: Hybrid Plow Blades	Maryland DOT
Snowplow Blades: Segmented Plow Blades	Massachusetts DOT
Snowplow Blades: Armored Carbide Snowplow Cutting Edges	Evolution Edges
Trucks and Snowplows: Tow Plows	Massachusetts DOT
Trucks and Snowplows: Automatic Vehicle Location (AVL) on Plow Trucks	North Dakota DOT
Trucks and Snowplows: Electric and Gas Trucks	Norwegian Public Roads Administration (PRA)
Trucks and Snowplows: Magna Wing on Triaxle Truck	Vermont AOT
*Contracting and Bidding: Short-Term Performance-Based Contracting**	Michigan DOT
*Contracting and Bidding: Multiple Award Bidding Process**	Pennsylvania DOT

* Contracting and bidding practices related to equipment and facilities are not highlighted in this executive summary but are summarized in the Practice Topic: Equipment and Facilities section of the report.

Four respondents identified but did not describe other new equipment and facilities practices:

- Transition from belt-driven to auger-driven spreaders (*Arizona*).
- Testing the salt reporting system in a local agency salt shed and continuing to report on liquid material use (*Michigan*).
- Use of flexible plow blades for District 7 trucks (*Nebraska*).
- Installation of floats on front plows to relieve down-pressure on plows (*South Dakota*).

Common Equipment and Facilities Themes

Common equipment and facilities themes centered around four topic areas: salt and brine, grip sensors, snowplow blades, and trucks and snowplows.

Salt and Brine. Six DOTs reported on making or applying brine and salt storage:

- *Arizona* added brine makers at strategic locations.
- *Colorado* uses brine, in conjunction with mobile sensors, to pretreat secondary roads ahead of major events.
- *Massachusetts* added to its first brine makers installed in 2010/2011 and pretreats roads using blended brine.
- *Nebraska* replaced old and worn-out brine-making facilities.
- *Texas* is building low-cost strategic reserve salt storage sheds.
- *Wyoming* purchased brine makers with controls mounted on trailers.

Grip Sensors. Two agencies described basing material use on friction sensor data:

- *Colorado DOT* tested mobile friction sensors on plows to make real-time material usage decisions.
- *Columbus, Ohio,* tried grip sensors to detect road surface grip, gather other data and employ dynamic spreading.

Snowplow Blades. Three respondents described new plow blade products:

- *Maryland DOT* tested hybrid plow blades in areas varying in elevation and climate.
- *Massachusetts DOT* uses two 4-foot plow blade sections combined with 3-foot sections of segmented blade with accessory equipment such as end guards.
- *Evolution Edges* offers a plow blade that incorporates Vibration Suppression Technology for reduced noise in the truck cab.

Trucks and Snowplows. Four agencies described practices associated with trucks and snowplows:

- *Massachusetts DOT* purchased tow plows for increased efficiency.
- *North Dakota DOT* equipped trucks with AVL.
- *Norwegian PRA* tested electric trucks on mountain passes.
- *Vermont AOT* pilot tested a Magna Wing configuration on a triaxle plow truck. A Magna Wing is described by its vendor as "an ultra-long wing that allows for one truck to do the work of two."

Practice Benefits and Challenges

Benefits of new equipment and facilities practices include:

- Cost savings (*Arizona, Colorado* and *Texas*) and increased efficiency for snow removal (*Massachusetts* and *Vermont*) or brine making (*Nebraska* and *Wyoming*).
- Reliance on live friction readings that take the guesswork out of road conditions and result in material savings (*Colorado*).
- Increased level of services, anti-icing and/or brine-making capacity (*Arizona*).

- Use of trucks that hold more material to help stretch staff capacity at night (*Vermont*).
- Practices that are effective in melting snow and ice (*Massachusetts* and *Columbus, Ohio*).
- Decreased wear on pavement markings and decreased driver fatigue (*Maryland*).
- Increased safety, including reducing in-cab noise to hear conversation; reduced wear and tear on plow gear (*Evolution Edges*).
- Lower carbon dioxide emissions from both operation and maintenance (*Norwegian PRA*).

Challenges of new equipment and facilities practices include:

- Up-front purchase or build costs (*Arizona*, *Columbus, Ohio,* and *North Dakota*). *Vermont AOT* reported that using a Magna Wing on a triaxle truck is nearly double the cost of a tandem axle truck.
- Ongoing training of new employees, as 45% of winter maintenance staff have three or fewer years of experience and the longer-tenured workforce may struggle with new technologies and adapting to change (*Colorado*).
- Pretreating roads in areas where storms may start as rain before freezing to ice or snow, which can result in valuable pretreatment materials being washed off the roads into waterways (*Massachusetts*).
- Locations serviced by brine trailers that require storage tanks (*Wyoming*).
- Vendors who may not want to work with competitors' equipment (*Columbus, Ohio*).
- End-user concerns regarding decreased level of service during winter operations (*Maryland*).
- Charging facilities that must be available and operational (*Norwegian PRA*).

Practices Unlikely to Continue

Massachusetts DOT tried tow plows but plans to use modern wing plows with enhanced roadway coverage rather than adding more tow plows. *Vermont AOT* will likely keep the pilot-tested Magna Wing on its triaxle truck unless the agency encounters hiring or vacancy issues. Cost may prevent this configuration from becoming standard operating procedure.

Materials Practices

Four transportation agencies described four new practices related to materials.

Practice	Agency or Partner
Mobile Detectors and Spreader Controllers to Control Salt Use	Massachusetts DOT
Direct Liquid Application (DLA) with Agricultural By-Products	Michigan DOT
Slurry Application	North Dakota DOT
Slurry Application	Norwegian PRA

Common Materials Themes

In addition to the Massachusetts practice of integrating road weather sensors with spreader controllers, other agencies described the benefits of a direct liquid or slurry application, with the latter modified by one agency to use a grinder that produces smaller salt stones.

Practice Benefits and Challenges

Benefits of new materials practices include:

- Directly basing salt use on road condition to conserve salt (*Massachusetts*).
- Using slurry, which is faster-acting than brine (*North Dakota*).

Challenges regarding these new materials practices involved the high costs for related equipment (*North Dakota*) and the initial setup of the DLA pilot study (*Michigan*).

Practice Unlikely to Continue

Michigan DOT's testing of an agricultural by-product was mandated by state statute. The agency implemented a pilot project comparing DLA with traditional rock salt application and issued a final report describing pilot results. The final report noted that while application of liquid agricultural by-products reduced environmental impacts, costs were greater when compared with traditional rock salt. The DLA practice has not been adopted for widespread use in treating winter storm events.

Training Practices

Seven respondents described eight new training practices. Two respondents, *Michigan* and *Pennsylvania DOTs*, reported work zone safety training as new practices that are included in the Practice Topic: Safety and Outreach portion of this report. *Michigan DOT* also reported developing a winter operator school that all new employees attend but did not provide details.

Practice	Agency or Partner
In-Person Snowplow Refresher	Arizona DOT
Snow Operations Equipment Endorsement Training	Colorado DOT
Tailgate Training for Snow and Ice Contractors	Massachusetts DOT
New Winter Operator Training	Nebraska DOT
Winter Maintenance Operations Testing	Norwegian PRA
Snowplow Simulators	Pennsylvania DOT
Science of Winter Training	Pennsylvania DOT
Winter Weather Training	Texas DOT

Common Training Themes

Common training themes centered around two topic areas: winter equipment and general winter maintenance.

Winter Equipment:

- *Arizona* and *Pennsylvania* employ snowplow simulators.
- Annual safety endorsement training in *Colorado* covers snowplows, wing plows and tow plows.
- *Massachusetts* conducts Tailgate Training for contractors that covers front-end loaders, salt spreaders and liquid tankers.

General Winter Maintenance:

- *Nebraska DOT* educates new operators on policies, procedures and equipment.
- Operators in *Norwegian PRA* are required to pass a test before engaging in winter operations.
- *Pennsylvania DOT* training covers the science of how winter materials work.
- *Texas DOT* offers winter response training for maintenance supervisors and managers.

Practice Benefits and Challenges

Benefits of new training practices include:

- Operators sharing knowledge (*Arizona* and *Massachusetts*).
- Increased safety and decreased accidents (*Colorado, Pennsylvania* and *Nebraska*).
- Providing awareness of environmental concerns (*Massachusetts*).
- Increased operational efficiencies (*Nebraska*) and preparedness (*Texas*).

Challenges of new training practices include:

- Cost (*Arizona, Massachusetts* and *Pennsylvania*).
- Operator travel (*Arizona*), scheduling (*Nebraska*) and time to train everyone (*Texas*).
- Ensuring contractors prepare personnel to pass the required test (*Norwegian PRA*).

Technology Practices

Seven respondents described new technologies employed in winter maintenance.

Practice	Agency or Partner
Mobile Road Condition Sensor	Arizona DOT
AVL and Road Weather Information System (RWIS) Program Expansion	Massachusetts DOT
Electronic Driver Inspection Reports (EDIR)	Michigan DOT
New AVL Provider	Nebraska DOT
Portable Maintenance Location Beacon	North Dakota DOT
Weather Station Alternatives	Norwegian PRA
AVL Expansion to Integrate Additional Tools	Pennsylvania DOT

Two respondents identified additional technology practices but did not provide further details. *Arizona DOT* uses WX Horizon software in RWIS and *North Dakota DOT* identified other technology-related practices:

- Apply integrated public alert and warning system (IPAWS) software for automated alerts on digital message signs.
- Use traffic control devices such as automated flagger assistance devices (AFADs), which are portable flagging stations, in new ways.
- Display signs on truck-mounted attenuator devices.

- Create digital twins to optimize variable speed limits.
- Employ GIS technology in inspection forms.
- Produce maintenance diaries and other new electronic forms on iPads.

Common Technology Themes

Common technology themes centered around two topic areas: AVL/Global Positioning System (GPS) uses and other technology tools.

AVL/GPS Uses:

- *Massachusetts* is expanding AVL and RWIS programs to better track salt distribution rates and weather parameters.
- *Pennsylvania* is testing turn-by-turn snow routes and dash cameras integrated into plow truck AVL systems.
- *Nebraska* is testing a new provider (Samsara) in its trucks.

Other Technology Tools:

- *Arizona* is testing the Vaisala Mobile Detector MD30 road surface data collector.
- *Michigan* is using EDIR to improve compliance with Driver Vehicle Inspection Reports (DVIRs) and communication.
- *North Dakota* is testing iPin location beacons in maintenance vehicles and on arrow/message boards.
- *Norwegian PRA* is testing small Internet of Things (IoT) weather stations that collect and transmit data on weather and road conditions.

Practice Benefits and Challenges

Benefits of new technology practices include:

- Provision of real-time road surface data (*Arizona*).
- Improved DVIR document management (*Michigan*).
- Showing the traveling public the location of maintenance crews (*North Dakota*).

Challenges of new technology practices include:

- Contractors' preference not to be monitored with GPS (*Massachusetts*).
- Costly RWIS infrastructure maintenance (*Massachusetts*) and buying new tools for trucks (*North Dakota*).
- Training and communication on new systems (*Michigan*).
- Using DOT staff to switch out AVL systems in trucks (*Nebraska*).

Safety and Outreach Practices

Seven respondents described nine new safety and outreach practices employed in winter maintenance.

Practice	Agency or Partner
Road Closure: Road Closure Plan	Nebraska DOT
Road Closure: Text Interstate Closures During Winter Storms	South Dakota DOT
Roadway Information: 511 Traveler Information	Massachusetts DOT
Roadway Information: iPad Cameras for Snowplows	North Dakota DOT
Roadway Information: Front-Facing Cameras on Plow Trucks	Pennsylvania DOT
Safety Training: Tabletop Work Zone Safety Training	Michigan DOT
Safety Training: Work Zone Training	Pennsylvania DOT
Variable Speed Limits (VSLs): Signs	Nebraska DOT
Variable Speed Limits: Integrated VSL Messaging with RWIS	Pennsylvania DOT

Two respondents identified but did not describe other new practices:

- *South Dakota* allows counties and tribes to enter road restrictions and closures into the 511 traveler system to improve communication and prevent re-routing through third-party navigation apps.
- *Massachusetts* is working with equipment outfitters on a new system to identify all state vehicles/assets in a work zone and time their strobes to flash in unison to decrease motorists' visual distortion or confusion night strobes can cause.

Common Safety and Outreach Themes

Common safety and outreach themes centered around four topic areas: road closure, roadway information, safety training and VSLs.

***Road Closure*.** Dynamic messages boards are used in *Nebraska* to announce road closures in areas with the most traffic from interstate and bordering state road closures, and *South Dakota* developed a text-in service system to send users updates on road closures during winter events.

Roadway Information:

- *Massachusetts* maintenance depots report roadway conditions on the agency's 511 website.
- *North Dakota* and *Pennsylvania* use front cameras on plows to transmit photos to 511 maps and through a Force America/PreCise subscription service, respectively.

Safety Training:

- *Michigan's* tabletop training is tailored to new hires based on regional traffic patterns and conditions.
- *Pennsylvania* developed training to share with schools on how to properly travel through and near work zones.

Variable Speed Limits. While *Nebraska* tried VSL but does not plan to continue, as described below, *Pennsylvania* is incorporating RWIS data to create alerts for VSL messaging when adverse conditions or other hazards are occurring.

Practice Benefits and Challenges

Benefits of new safety and outreach practices include:

- Ensuring the traveling public is aware of road conditions, and improved messaging that delivers timely, clear and concise information to the public (*Massachusetts, Nebraska, North Dakota, Pennsylvania* and *South Dakota*).
- Adopting safety training that helps participants understand safety requirements under different scenarios (*Michigan*).
- Reducing crashes and injuries (*Pennsylvania*).

Challenges of new safety and outreach practices include:

- Covering all road conditions during active snowfall and a potential two-hour gap between reporting road conditions and a 511 user reading about them (*Massachusetts*).
- Focusing work zone safety on construction, which may not cover all maintenance issues (*Michigan*).
- Funding (*North Dakota* and *Pennsylvania*).
- Managing imaging retention policy for records requests (*Pennsylvania*).

Practice Unlikely to Continue

Nebraska DOT will not use VSL as a standard operating procedure, citing the following factors:

- No regulatory authority to mandate
- Cost
- Operational breakdowns
- Using effectively (for example, determining appropriate speeds for conditions)

The agency does not recommend the practice for other agencies.

Emerging Practices

Survey respondents reported varied interest in emerging technologies and practices that are not currently market-ready but estimated to be publicly available within the next five years. Highlights are summarized in five topic areas:

- ***Artificial intelligence*.** Respondents reported general interest in using artificial intelligence (AI) for planning (*Arizona* and *Pennsylvania*) and technology practices (*Arizona* and *North Dakota*). Other reported interest in uses of AI:
    - Assessing road conditions, providing updates (*South Dakota*) and road closure assistance (*Massachusetts*).
    - Snowplow routing (*Pennsylvania*).
    - Weather forecasting (*Pennsylvania* and *Texas*).
- ***Forecasting*.** Two respondents noted the importance of improved tools for forecasting pavement condition (*Nebraska*) and road salting (*Norwegian PRA)*.

- ***Materials Practices*.** Increased efficiency in materials usage is a common interest, including automated salt inventory control in *Michigan* and *North Dakota's* goal of efficient operations and materials use.
- ***Equipment*.** Improved wash bays and best practices for winter equipment (*Pennsylvania*) and different lighting techniques for winter operations vehicles (*Wyoming*) are examples of emerging equipment interests.
- ***Training*.** Driver simulator effectiveness (*Michigan*) and enhanced, hands-on operator training (*Pennsylvania*) are emerging training topics of interest.

Barriers or challenges in exploring or testing emerging technologies were related to:

- Bureaucracy (*Arizona* and *North Dakota*).
- Costs (*Arizona*, *Columbus*, *Ohio,* and *South Dakota*).
- Data or IT issues (*Michigan* and *Pennsylvania*).
- Leadership or staff support (*Columbus*, *Ohio*, *South Dakota* and *Wyoming*).
- Technology challenges (*Columbus*, *Ohio,* and *Massachusetts*).

Winter Maintenance Challenges and Strategies

Looking forward, survey respondents noted common challenges their winter maintenance programs currently face or expect to encounter in the next five years. In addition to long-standing concerns such as costs and staffing, respondents commented on issues related to equipment, materials and technology.

Increasing traffic (*Arizona* and *Texas*) and climate conditions were also highlighted, including variable winter weather (*Massachusetts*), increased heavy snowfall (*Norwegian PRA*) and extreme weather conditions (*Texas*).

Respondents described the types of support they receive from their agencies to meet these challenges:

- Compensation strategies (*Massachusetts* and *South Dakota*).
- Employee training (*Michigan, Kentucky* and *Nebraska*).
- Funding (*Arizona* and *Kentucky*).
- Infrastructure and equipment (*South Dakota*).
- Willingness to try new ideas (*Arizona, Nebraska, North Dakota* and *Texas*).

Recommendations and Lessons Learned

Respondents offered recommendations for agencies seeking new practices to address winter maintenance challenges in four topic areas:

- ***Collaboration***. Communicate and work with internal and external stakeholders.
- ***Funding.*** Seek grants or partnering with other agencies.
- ***Research and planning.*** Stay current on research, ensure a thorough understanding of technology, identify needs and support other planning functions.
- ***Training and safety.*** Maintain a focus on training and safety.

Lessons learned by implementing new practices can be organized around several common themes:

- Collaboration and communication (*Michigan, Kentucky, North Dakota* and *Norwegian PRA*).
- Internal and external education (*Kentucky, Massachusetts, Nebraska, Pennsylvania* and *Texas*).
- Operational considerations (*Colorado, Massachusetts, North Dakota* and *Norwegian PRA*).

Examining the Literature

A literature search gathered information to supplement findings from the survey of winter maintenance professionals. In addition to pertinent Clear Roads research projects — in process and completed — and articles on overarching themes in winter maintenance advancements, the search identified a sampling of resources addressing recent or leading-edge practices in winter maintenance in the six categories used to organize Clear Roads research:

- Planning
- Equipment (including facilities)
- Materials
- Training
- Technology
- Safety (including outreach)

Presented below are selected highlights from these resources.

Planning Practices

Efforts to improve winter operations include:

- A 2025 Michigan DOT exploration into using a winter severity index as a proxy for estimating winter maintenance material costs to optimize operational efficiency and financial planning.
- Federal Highway Administration's 2021 examination of the use of AI to collect and analyze data that could dramatically improve winter maintenance operations, safety and mobility by integrating into maintenance decision support systems (MDSS).
- A recent Utah DOT study that developed potential strategies to enhance public communications during snow events, including prioritizing critical areas, coordinating with other agencies and integrating advanced technologies.

Equipment and Facilities Practices

Two studies examined the fuel efficiency of snowplow fleets. A 2025 paper outlines a method to correlate fuel usage and vehicle weight with snowfall for improved fleet management strategies such as optimizing deicing loads or exploring the feasibility of snowplow electrification. Minnesota DOT (MnDOT) analyzed the impact that idling and snowfall have on the fuel consumed by MnDOT's snowplow fleet to identify ways to reduce fuel usage using vehicle telematics data.

Snowplow safety was the focus of a 2023 MnDOT project that developed a snowplow driver-assist system for use in demanding low-visibility situations. The lane guidance system developed uses advanced GPS systems and roadway maps to provide information and alerts to drivers about their roadway position. Also focused on safety, a 2024 Utah DOT project sought to enhance winter road safety management with an AI model and methods to evaluate snow cover conditions on road surfaces using existing roadside closed-circuit television system images where RWIS data is not available.

Materials Practices

Explorations into new materials practices include in-progress research to develop precast concrete with self-powering defrosting capability; other research analyzed the impacts of an observed increase in freeze-thaw events on pavement systems. A 2023 Ohio DOT study examined snowplow liquid deicing material use and the tracking capabilities of a plow's distribution system to inform the agency's selection of new liquid tracking technologies to test, all with an eye toward optimizing winter weather responses.

Training Practices

Simulators are a popular topic in new and emerging training practices. Ongoing research at Ohio DOT is developing customized simulation capability that can mimic snowplow operations and actual Ohio roadways with snow and ice for deployment as custom training environments and scenarios. An Indiana DOT study synthesized information from multiple sources, including other state DOTs, to identify the benefits and challenges of simulators for snowplow driver training. Researchers recommended that Indiana DOT continue to explore the use of simulators to supplement the agency's annual snowplow driver training.

Technology Practices

Rapid advancements in technology for a wide variety of transportation maintenance purposes are reflected in a current research project investigating whether connected vehicle sensor data can serve as a reliable alternative for pavement friction monitoring to support proactive agency maintenance and improved roadway safety. A 2024 Indiana DOT study explored the use of connected vehicle data coupled with enhanced weather data and fleet telematics used in winter operations activities to evaluate the robustness of the MDSS forecasts.

A 2023 National Cooperative Highway Research Program playbook identified issues and opportunities for state DOTs for management of and adaptation to disruptive technologies. A 2025 study explored the relationship between winter severity indices and maintenance costs through a nationwide survey of state DOTs and Clear Roads survey data.

Safety and Outreach Practices

Safety-related research with a focus on decreasing crash risk includes a North Dakota DOT study in progress that is examining historical crash data to identify high-risk roadway areas showing elevated crash frequencies and severe adverse road surface conditions. Using this data, researchers will develop a method for estimating and predicting crash occurrences related to adverse weather conditions. Similarly, a 2025 study analyzed snowplow-involved crash hotspots in Wyoming to identify problem areas. Researchers have also used connected vehicle data indicating incident-induced delays and harsh braking events to investigate the impacts of winter maintenance operations on road safety under different weather conditions.

1 Introduction

1.1 Background

Changes in the factors impacting how transportation agencies manage snow and ice can be both challenging and promising. State departments of transportation (DOTs) continue to experience resource constraints and increasing driver shortages. As environmental changes create additional uncertainty, winter maintenance managers need to balance these challenges, find efficiencies and improve performance.

Clear Roads members requested this synthesis to explore new and emerging practices, procedures and equipment used in fighting snow and ice across a range of topic areas. Members are interested in transportation agency experiences and academic perspectives on the latest innovations, trends and hurdles in managing winter maintenance operations.

1.2 Project Description

A three-part strategy gathered information for this synthesis:

- *Survey of winter maintenance professionals*. A survey of Clear Roads member states and selected partner agencies (Norwegian Public Roads Administration (PRA)) gathered information about the latest technologies and leading-edge winter maintenance practices. The survey sought information about a range of issues, including:
    - New practices across the six Clear Roads research areas
    - Emerging technologies and practices
    - Challenges in implementing new practices
    - Recommendations and lessons learned
- *Outreach to other winter maintenance experts.* Email outreach to a select group of other winter maintenance experts gathered additional perspectives on the latest developments in winter maintenance. These results are presented with Clear Roads member survey responses.
- *Literature search*. An examination of publicly available domestic resources and in-progress research sought information about new and emerging winter maintenance practices, procedures or tools.

1.3 Survey Response

Nineteen respondents representing 16 Clear Roads member states and partner agencies responded to the survey:

State Department of Transportation Members

- Arizona
- Colorado
- Kentucky
- Maryland
- Massachusetts
- Michigan
- Nebraska (three responses)
- Nevada
- North Dakota
- Oregon
- Pennsylvania
- South Dakota (two responses)
- Texas
- Vermont
- Wyoming

Partner Agencies

- Norwegian PRA

Nebraska DOT submitted three responses:

- District Operations and Maintenance Manager (DOMM)
- Highway Maintenance Superintendent (HMS)
- Winter Maintenance Engineer (WME)

South Dakota DOT submitted two responses:

- Operations (Ops)
- Director of Operations (DO)

Three winter maintenance experts responded to email queries or were interviewed by phone:

- City of Columbus, Ohio, Department of Public Service
    - Infrastructure Operations Coordinator
- Evolution Edges, a division of Chemung Supply Corporation
    - Consulting Engineer
- Vaisala, Inc.
    - Business Application Manager

Their responses are presented with survey findings.

Survey questions are provided in Appendix A. The full text of survey responses, including respondent contact information, is available to Clear Roads members separately.

1.4 Organization of This Synthesis Report

Chapter 2 presents survey findings in four topic areas:

- New snow and ice practices
- Emerging technologies and practices
- Winter maintenance challenges and strategies
- Lessons learned from implementing new practices

Chapter 3 supplements survey findings with a summary of relevant literature. The report's appendix provides the survey questions.

While the survey conducted for this synthesis received responses from nearly 40% of the 39 Clear Roads members, as well as responses from a small number of other winter maintenance experts, the survey findings do not serve as a representative sampling of all public transportation agencies. These results will, however, inform the practices of winter maintenance managers seeking to identify and implement new and emerging practices to manage snow and ice.

2 New and Emerging Snow and Ice Practices

2.1 Introduction

Sixteen Clear Roads member and partner agencies and three additional winter maintenance experts shared experiences and perspectives on the latest innovations, trends and hurdles in managing winter maintenance operations. These survey respondents provided information for more than 60 new and emerging practices, procedures and technologies used to manage snow and ice in six topic areas Clear Roads Research Program uses to organize research and projects:

- Planning
- Equipment (including facilities)
- Materials
- Training
- Technology
- Safety (including outreach)

The survey provided limited opportunities for respondents to describe in detail new practices in each topic area. For each topic area discussed in the following sections, the practices described by respondents are followed by additional practices identified but not described.

Table 1 identifies the 53 new practices described by respondents by topic area. If a respondent described more than one new practice, the total number of practices described by a responding agency in a particular topic area is reflected in parentheses.

Table 1. New Practices Described by Respondents

State Agency Respondent or Partner	Planning	Equipment and Facilities	Materials	Training	Technology	Safety and Outreach
Arizona		X		X	X	
Colorado	X	X (2)		X		
City of Columbus, Ohio		X				
Evolution Edges		X				
Maryland		X				
Massachusetts	X	X (3)	X	X	X	X
Michigan		X	X		X	X
Nebraska DOMM	X					X
Nebraska HMS		X		X	X	X
Nebraska WME	X					
North Dakota	X	X	X		X	X
Norwegian PRA		X	X	X	X	
Pennsylvania		X		X (2)	X	X (3)
South Dakota DO	X					X
Texas		X		X		
Vermont	X	X				
Wyoming	X	X				
Total	**8**	**17**	**4**	**8**	**7**	**9**

Three respondents did not describe new practices in any of the six research areas examined in the survey but did address other survey questions as noted below:

- *Kentucky DOT* addressed questions regarding Winter Maintenance Challenges and Strategies and Lessons Learned from Implementing New Practices.
- *Oregon DOT* addressed questions related to Winter Maintenance Challenges and Strategies.
- *South Dakota Ops* identified a new planning practice but did not describe it. The respondent provided information on Emerging Technologies and Practices, Winter Maintenance Challenges and Strategies and Lessons Learned from Implementing New Practices.

The *Nevada DOT* respondent did not provide information about new or emerging practices.

2.2 Practice Topic: Planning

Eight respondents described new planning practices in winter maintenance:

- **Resource Management and Proper Material Usage** (*Colorado*). Provide training to winter operators on storm forecasting, friction data and material parameters to balance levels of service with safety of the traveling public.
- **Performance Metric for Salt Use** (*Massachusetts*). Examine salt usage in the context of winter severity with a linear regression to assess the efficiency of salt usage.
- **Preemptive Interstate Closure** (*Nebraska DOMM*). Allow agency plow operators to keep working without traffic, resulting in quicker reopening of the interstate.
- **Winter Severity Index Mapping** (*Nebraska WME*). Create a map that provides a visual indicator of forecasted winter weather severity.
- **Salt Use Goal** (*North Dakota*). Implement a maintenance goal related to the ratio of salt (tons) to liquids (gallons) used for snow and ice melting.
- **Winter Severity Indices for Budget Planning** (*South Dakota DO*). Apply a winter severity index to normalize historical expenditures and anticipate needs.
- **Streamlining Route Logs and Tracking Materials Usage** (*Vermont*). Attempt to streamline route logs and track materials usage using an iPad or iPhone connected to the spreader controller.
- **Personnel and Equipment Resource Sharing** (*Wyoming*). Share both personnel and equipment to manage snow and ice storms.

Details are provided in the practice summaries below.

The *South Dakota DO* respondent identified but did not describe a new planning practice that uses traffic speeds to consider operational decisions and analyze post-storm performance.

Resource Management and Proper Material Usage (Colorado)

Topic	Description
Practice	Maintenance supervisors focus on several resource management tools in training winter operators to balance levels of service with safety of the traveling public: • The Pikalert weather system uses National Center for Atmospheric Research weather data sources and vehicle-based road and atmospheric measurements to infer road conditions illustrated on color-coded map displays (Figure 1). • Friction sensors (see the Equipment Practices section of this report), including stationary sensors across the state and mobile sensors on supervisor and plow trucks, support treating hazardous locations and decision-making across all winter operational aspects. • A De-Icer Product Guide within the SnowPlow Quick Guide describes application ranges, working temperatures, and pros and cons of deicer products (see Supplement A).

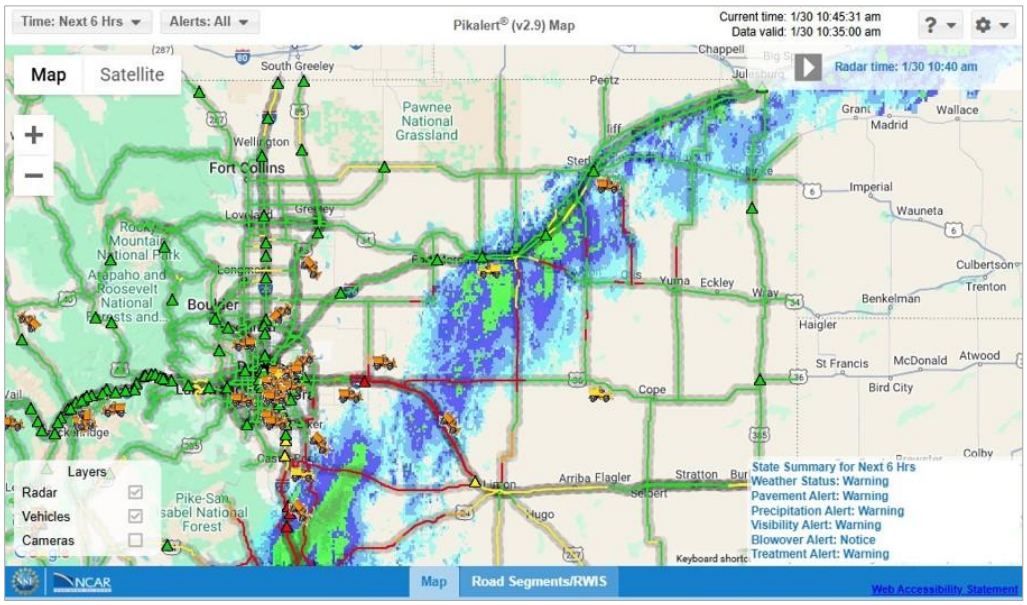


Figure 1. Screenshot of Colorado DOT's Pikalert Weather System

(*Source*: *Colorado DOT*)

Topic	Description
Challenges	• Need for constant training due to winter operator turnover. • Retraining veteran operators. • Training to address wet roads during a storm is not funded.
Benefits	• Immediate results. • Efficient snowstorm management. • Material and overtime savings. • Decreased equipment wear and tear.

Topic	Description
Future Use	**Colorado DOT** implements ”ride-alongs” at the start of every season. **Other agencies** can offer detailed training on pre- and post-storm planning, including mobile friction usage, calibration and training on material parameters.
Related Resources	**SnowPlow Quick Guide, De-Icer Product Guide and Plowing Considerations**, Colorado Department of Transportation, undated. See Supplement A. **Winter Operations and Wing Training**, Colorado Department of Transportation, undated. See Supplement B. This training presentation includes a Pikalert tutorial and review of the 2024-2025 winter operations statewide plan. A discussion of friction sensors is followed by a review of the quick guides appearing in Supplement A. The presentation concludes with a wing operation review.

Performance Metric for Salt Use (Massachusetts)

Topic	Description
Practice	Working with the agency’s Environmental Services Division, Massachusetts DOT started assessing salt usage against a winter's severity over a decade ago when prewetting salt at the spinner to pretreat roads with blended brine. Salt dispensation was dependent on vehicle speed. By assessing salt usage against winter severity with a linear regression, the agency can determine which seasons yielded a data point below the line of best fit, representing an efficient season.
Challenges	None reported.
Benefits	Supports efficient operations by analyzing available data.
Future Use	**Massachusetts DOT** continues its annual assessment of salt usage at statewide and district levels as an important season review function. **Other agencies** can employ this practice if salt usage data for multiple seasons is available and a winter severity value can be retrospectively determined. Potential users must identify a winter severity index that uses readily available data.
Related Resource	**Weather Severity Index vs Salt Usage 2001-2025**, Massachusetts Department of Transportation, undated. See Supplement C. This Excel workbook illustrates the assessment described above.

Preemptive Interstate Closure (Nebraska DOMM)

Topic	Description
Practice	This practice allows the agency to determine that an interstate closure is needed preemptively, particularly in areas where winter weather events are expected to have a significant impact on travelers. With such a closure, agency plow operators are able to keep working without traffic, allowing the interstate to open sooner.

Topic	Description
Challenges	• Correctly timing the closure. • Providing parking for trucks impacted by the closure. • Google maps direct traffic onto county roads.
Benefits	• Safety of the traveling public. • Decreased crashes during storm events.
Future Use	**Nebraska DOMM** did not report on future use of preemptive interstate closures. **Other agencies** can adopt a similar policy or practice to keep vehicles off interstates when significant winter weather events are expected.
Related Resource	November 2025 Newsletter, Nebraska DOT Traffic Incident Management. This newsletter contains a brief article on preemptive closures.

Winter Severity Index Mapping (Nebraska WME)

Topic	Description
Practice	Working with Nebraska DOT's Operations Division, the University of Nebraska-Lincoln created a map that provides a visual indicator of forecasted winter weather severity.
Challenges	• Severity classification. • Forecast accuracy.
Benefits	Ability to prepare for events, including moving equipment and personnel to high-impact areas when appropriate.
Future Use	**Nebraska DOT** does not widely use index mapping as it is often easier to determine highly impacted areas without the tool. As such, the mapping tool is not likely to become standard operating procedure. The practice is not recommended for **other agencies**.
Related Resource	Development of the Nebraska Department of Transportation Winter Severity -- Phase II, Nebraska Department of Transportation, May 2024. *From the abstract*: [T]his study builds on the previously developed NEWINS [Nebraska Winter Severity Index] by creating a predictive winter storm severity index known as NEWINS-Predictive (NEWINS-P).

Salt Use Goal (North Dakota)

Topic	Description
Practice	North Dakota DOT applies a blend of water and salt with a sugar beet mixture to melt snow and ice in temperatures well below 0°F. Seeking to improve its efficiencies in salt use and informed by research and guidance developed by other state DOTs, North Dakota DOT implemented a maintenance goal related to the ratio of liquids (gallons) to salt (tons) used for snow and ice melting. The new resource efficiency practice is based on a Minnesota DOT (MnDOT) goal of increasing the ratio of liquids to solids to deice roads. By 2027, MnDOT's target is to use 200 gallons for every ton of solids used. Wisconsin DOT research on the efficiency of salt brine use also influenced the new North Dakota DOT goal.
Challenges	Legislative funding.

Topic	Description
Benefits	• Efficiency ratio (Efficiency = Brine (Gal)/Salt (Ton)) has increased by 12 in the past year. • More efficient operations clear highways faster.
Future Use	**North Dakota DOT** hopes to reach its maintenance goal within 10 years and provide justification for funding of liquid application equipment. **Other agencies** can identify a salt use goal and track amounts of liquid and solid salt used.
Related Resources	**Performance Measure Dashboard: Snow and Ice Removal**, Minnesota Department of Transportation, 20265. This performance dashboard displays the ratio of liquid to solid deicing chemicals for snow and ice control. **Evaluation of Winter Maintenance with Salt Brine Applications in Wisconsin**, Wisconsin Department of Transportation, December 2021. *From the abstract*: Key findings of this research indicate that salt brine applications reduced the amount of salt used, improved time to bare/wet, present better pavement friction conditions, and benefits outweighed the cost of investment to introduce salt brine to existing solid salt applications.

Winter Severity Indices for Budget Planning (South Dakota DO)

Topic	Description
Practice	South Dakota DOT's winter maintenance budgets for South Dakota DOT have been highly dependent on winter weather and the number of snow and ice events occurring each year. Traditionally, the agency has used historical averages. Winter severity indices normalize historical expenditures to anticipate needs. Budget requests 125% above a "normal" year provide adequate resources when winter severity exceeds that of a normal year.
Challenges	Defining or explaining what a severity index is and how it supports estimating future budget needs.
Benefits	• Provides logical method to communicate budget needs for winter-related supplies to decision-makers. • Provides systematic and repeatable method to analyze and request additional funding as needed.
Future Use	**South Dakota DOT** uses winter severity indices as a standard operating procedure. **Other agencies** can adopt a similar process to review resource and budget needs.

Streamlining Route Logs and Tracking Materials Usage (Vermont)

Topic	Description
Practice	An asset management company attempted to streamline route logs and the tracking of materials usage using an iPad or iPhone connected to the spreader controller to obtain material usage and route information.
Challenges	Practice did not work as expected.

Topic	Description
Benefits	Intent of this practice was to streamline route log and tracking and verification of material usage.
Future Use	**Vermont AOT** has not adopted streamlined route logs and materials tracking.

Personnel and Equipment Resource Sharing (Wyoming)

Topic	Description
Practice	To address equipment, staffing and funding limitations, many Wyoming DOT districts began sharing both personnel and equipment to manage snow and ice storms.
Challenges	• Managing logistics for every storm. • Quickly moving equipment and personnel around based on weather forecasting and availability where and when needed.
Benefits	• As storms don't occur statewide, equipment and personnel can be sent to impacted areas. • Savings on equipment availability across the state. • Sharing personnel helps locations that struggle with hiring.
Future Use	While not formal standard operating procedure, the resource sharing practice will continue within **Wyoming DOT**, managed by the districts. The practice could easily adopted by **other agencies**.

2.3 Practice Topic: Equipment and Facilities

Fourteen respondents described 17 new practices associated with equipment and facilities:

- **Salt and Brine Practices: Brine-Making Equipment** (*Arizona*). Add brine makers at strategic locations.
- **Salt and Brine Practices: Brine Use in Conjunction with Mobile Sensors** (*Colorado*). Use mobile sensors to improve the use of brine to pretreat secondary roads ahead of major events.
- **Salt and Brine Practices: Brine-Making Equipment and Brine Use** (*Massachusetts*). Add to first brine makers installed in 2010/2011; apply blended brine as a pretreatment.
- **Salt and Brine Practices: Brine-Making Facilities** (*Nebraska HMS*). Replace old and worn-out brine-making facilities.
- **Salt and Brine Practices: Salt Storage Facilities** (*Texas*). Design and build low-cost strategic reserve salt storage sheds.
- **Salt and Brine Practices: Brine-Making Equipment** (*Wyoming*). Purchase brine makers with controls mounted on trailers.
- **Grip Sensors: Mobile Friction Sensors** (*Colorado*). Test the use of mobile friction sensors on plows to make real-time material usage decisions.
- **Grip Sensors: Road Surface Grip Sensors** (*Columbus, Ohio*). Try grip sensors to detect road surface grip, gather other data and employ dynamic spreading.
- **Snowplow Blades: Hybrid Plow Blades** (*Maryland*). Test hybrid plow blades in areas varying in elevation and climate.

- **Snowplow Blades: Segmented Plow Blades** (*Massachusetts*). Use two 4-foot plow blade sections combined with a 3-foot section of segmented blade with accessory equipment such as end guards.
- **Snowplow Blades: Armored Carbide Snowplow Cutting Edges** (*Evolution Edges*). Try a plow blade that incorporates Vibration Suppression Technology for reduced noise in the cab of the snowplow.
- **Trucks and Snowplows: Tow Plows** (*Massachusetts*). Purchase tow plows for increased efficiency.
- **Trucks and Snowplows: Automatic Vehicle Location (AVL) on Plow Trucks** (*North Dakota*). Equip trucks with AVL**.**
- **Trucks and Snowplows: Electric and Gas Trucks** (*Norwegian PRA*). Test electric trucks on mountain passes.
- **Trucks and Snowplows: Magna Wing on Triaxle Truck** (*Vermont*). Test a Magna Wing configuration on a plow truck.
- **Contracting and Bidding: Short-Term Performance-Based Contracting** (*Michigan*). Try performance-based contracting for essential maintenance needs.
- **Contracting and Bidding: Multiple Award Bidding Process** (*Pennsylvania*). Use a contracting process to secure more trucks.

Details are provided in the practice summaries below.

Four respondents identified but did not describe other new practices:

- Transition from belt-driven to auger-driven spreaders (*Arizona*).
- Test the salt reporting system in a local agency salt shed and continue to report on liquid material use (*Michigan*).
- Use flexible plow blades for District 7 trucks (*Nebraska HMS*).
- Install floats on front plows to relieve down-pressure on plows (*South Dakota DO*).

Brine-Making Equipment (Arizona)

Topic	Description
Practice	Arizona DOT added brine makers at strategic locations based on industry standards and input from other states.
Challenges	Up-front costs to purchase and build the facility.
Benefits	• Cost savings. • Increased level of service. • Increased anti-icing capabilities and brine-making capacity.
Future Use	**Arizona DOT**'s use of the brine-making equipment is ongoing. **Other agencies** can identify potential additional locations for brine production by examining data and performing cost–benefit analyses of in-house brine production.

Brine Use in Conjunction with Mobile Sensors (Colorado)

Topic	Description
Practice	Used in conjunction with mobile friction sensors, discussed in the New Equipment Practices section, Colorado DOT is using brine for pretreating secondary roads ahead of major events.
Challenges	Need to constantly train new employees as 45% of winter maintenance staff have three or fewer years of experience.
Benefits	Reduced costs and positive results using brine to prewet materials and pretreating roads with a bond breaker.
Future Use	Annual training continues at **Colorado DOT** and more sensors will be added to the snowplow fleet as resources allow. **Other agencies** can consider the use of mobile friction sensors when applying brine.

Brine-Making Equipment and Brine Use (Massachusetts)

Topic	Description
Practice	Supplementing the first brine makers installed in 2010/2011 in Sagamore, Massachusetts DOT added two more brine makers, one in Deerfield around 2019/2020. The Deerfield brine facilities project cost $4 million and failed to meet its projected schedule. Another brine maker was recently placed in an existing wash bay building in District 3, which is both hilly and chilly with more pretreatment opportunities. The District 3 project was about 10% of the cost of the Deerfield brine maker.
Challenges	The Sagamore facility is in an area where many winter events start as rain before freezing to ice or snow. These events can wash valuable pretreatment materials off the roads into waterways.
Benefits	Using blended brine (85% of saturated sodium chloride solution, which is about 23.4% sodium chloride in water), plus 15% of a 28.5% magnesium chloride brine for deicing boost is an effective pretreatment for snow and ice events.
Future Use	Increased brine making has expanded **Massachusetts DOT's** pretreatment capabilities and pretreating roadways as needed is standard operating procedure. Brine can be hauled between districts to serve those with no brine-making capacity. **Other agencies** can work with Marc Valenti, a Clear Roads research consultant and a pioneer of different brines to fight snow and ice. Marc is associated with BrineTechnologies, a company that "design[s] and build[s] premium state-of-the-art brine makers and truck filling systems."

Brine-Making Facilities (Nebraska HMS)

Topic	Description
Practice	New brine-making facilities are replacing old and worn-out brine-making facilities.
Challenges	• Creating room in maintenance yards. • Designing brine-making facilities to meet a specific location's needs.

Topic	Description
Benefits	Buildings and areas dedicated solely to brine making result in more efficient brine-making operations.
Future Use	**Nebraska DOT** will install a new brine facility to be functioning in six to eight months. **Other agencies** can consider designating appropriate areas solely for brine making.

Salt Storage Facilities (Texas)

Topic	Description
Practice	Texas DOT's Maintenance Division is designing and funding five low-cost strategic reserve salt storage sheds.
Challenges	None currently.
Benefits	• Decrease salt storage costs. • Expand strategic reserve salt.
Future Use	**Texas DOT's** salt storage project should be completed this year. **Other agencies** can readily use this practice.

Brine-Making Equipment (Wyoming)

Topic	Description
Practice	Maintenance and district staff suggested the recent purchase of brine makers with all controls mounted on trailers to help lower brine cost and improve availability.
Challenges	Locations serviced by brine trailers will need storage tanks.
Benefits	• Trailers can accommodate the needs of locations around state. • Brine-making facilities are not needed at each maintenance location.
Future Use	Depending on outcomes, the practice could become standard operating procedure within a few years at **Wyoming DOT**. **Other agencies** can use brine trailers as an alternative to building brine plants.
Related Resource	**BrineXtreme Advantage: Professional Grade Road Salt Brine Maker**, Henderson Products, Inc., 2025. This website provides a product description.

Mobile Friction Sensors (Colorado)

Topic	Description
Practice	Vendor relationships spurred a pilot effort to install mobile friction sensors on plows to make real-time data-driven decisions on material usage.
Challenges	At times, the longer-tenured workforce struggles with new technologies and adapting to change.
Benefits	Reliance on live friction readings takes the guesswork out of assessing road conditions and results in material savings.

Topic	Description
Future Use	**Colorado DOT** is considering different ways to add sensors to plow trucks and will add more to its snowplow fleet as budget allows. **Other agencies** can consider piloting the use of mobile friction sensors on selected plow trucks.

Road Surface Grip Sensors (Columbus, Ohio)

Topic	Description
Practice	Vehicle-mounted, fixed and virtual grip sensors detect road surface grip and gather other data. Sensors connected to the vehicle's hydraulic system for high efficiency allow for dynamic spreading.
Challenges	• Vendors may not want to work with competitors' sensors. • Sensors can be expensive and must be attached to every truck in the fleet for the most efficient operation.
Benefits	As low grip surfaces are identified, salt can dispense to melt the ice and snow and improve grip.
Future Use	**Other agencies** can use road surface grip sensors.

Hybrid Plow Blades (Maryland)

Topic	Description
Practice	Three Maryland DOT facilities varying in elevation and climate in urban and rural regions tested unspecified hybrid plow blades. Facilities selected for the pilot allowed the agency to assess blade use across a broad spectrum of experiences and conditions.
Challenges	End-user concerns of decreased level of service during winter operations.
Benefits	• Increased snow removal efficiency. • Reduced driver fatigue. • Decreased wear on pavement markings.
Future Use	The hybrid plow blades performed as advertised and are used in 24 of 28 **Maryland DOT** facilities. **Other agencies** can start small by piloting the use of hybrid plow blades.

Segmented Plow Blades (Massachusetts)

Topic	Description
Practice	Massachusetts DOT has switched to segmented plow blades: Two 4-foot plow blade sections are combined with a 3-foot section of segmented blade with accessory equipment such as end guards.
Challenges	None noted.
Benefits	Easier to install and manage as compared to traditional 11-foot blades.

Topic	Description
Future Use	Use of segmented plow blades is ongoing at **Massachusetts DOT**. Many **other agencies** have transitioned to segmented blades.

Armored Carbide Snowplow Cutting Edges (Evolution Edges)

Topic	Description
Practice	Evolution Edges VST Armored Carbide Snowplow Cutting Edges incorporate Vibration Suppression Technology (VST) into an armored carbide snowplow cutting edge encased in rubber to reduce noise in the cab of the snowplow. The cutting edges are available in 1-, 3- and 4-foot lengths.
Challenges	None noted; fits standard DOT plows.
Benefits	• Overall safety, including reducing noise to hear conversation. • Reduced wear and tear on plow gear and prominent wear indicators showing when blade changes are required. • Simplicity and overall value.
Future Use	Several Clear Roads member agencies currently use Evolution Edges blades.
Related Resources	**Innovative Blades and Cutting Edges: Sabre Stealth VST**, Evolution Edges, 2026. This website contains product details. **Introducing the Sabre Stealth VST Blade: Your Trusted Companion for Reliable Plowing,** Chemung Supply Corporation, 2023. This press release describes the Sabre Stealth VST Blade.

Tow Plows (Massachusetts)

Topic	Description
Practice	Massachusetts DOT purchased 19 tow plows for statewide use.
Challenges	Prone to corrosion in particular linkages.
Benefits	Increased efficiency.
Future Use	**Massachusetts DOT** plans to purchase modern wing plows with enhanced roadway coverage rather than adding any more tow plows to its fleet.

AVL on Plow Trucks (North Dakota)

Topic	Description
Practice	Motivated by other states using AVL, North Dakota DOT began by equipping a few plow trucks with this technology. At the time of publication, Norh Dakota DOT had completed installation of AVL on its fleet of 353 trucks.

Topic	Description
Challenges	This large, complicated project required information technology expertise and coordination among North Dakota DOT, North Dakota Information Technology (NDIT), all agency districts and the vendor. While installation began with the vendor, workmanship that failed to meet contractual requirements led the agency to use North Dakota DOT forces to complete the installation.
Benefits	Even though the transition from vendor to agency forces for installation led to overtime, delays, additional coordination and staffing challenges, the project was completed and deemed a worthwhile effort. Newly outfitted trucks are able track material use during winter operations.
Future Use	**Other agencies** can select an AVL provider and contract for the service.

Electric and Gas Trucks (Norwegian PRA)

Topic	Description
Practice	The director of Norwegian PRA recommended testing electric trucks on two mountain passes. Reports describing their use are in development.
Challenges	Charging facilities must be available and operational.
Benefits	Lower carbon dioxide (CO_2) emissions from both operation and maintenance.
Future Use	**Contractors** compete for maintenance contracts and reductions in CO_2. The agency has noted that contractors purchase both electric and gas-driven trucks that are used for all-season maintenance operations. **Other agencies** can consider nonmonetary criteria when acquiring vehicles for winter maintenance.

Magna Wing on Triaxle Truck (Vermont)

Topic	Description
Practice	A vendor demonstration sparked operator interest in a Magna Wing truck plow configuration. The Magna Wing is described by its vendor as “an ultra-long wing that allows for one truck to do the work of two.” A pilot test last season was positive overall, with a few minor issues.
Challenges	Cost is almost double as compared to a tandem axle truck.
Benefits	• Truck can hold more material, which allows for stretching night routes when staffing is reduced. • Savings and increased efficiencies — a single truck clears both lanes of interstate.
Future Use	**Vermont AOT** will likely keep the Magna Wing configuration unless the agency encounters hiring or vacancy issues, but costs may prevent this configuration from becoming standard operating procedure. **Other agencies** appear to be considering this equipment, as there are a few vendors selling similar products with an extra-long wing setup.

Topic	Description
Related Resource	**Magna Wing: Double Your Truck, Double Your Work,** Viking Cives, 2023. This publication provides a product description.

Contracting and Bidding Practices

While not directly describing new or innovative equipment or facilities, two respondents described practices outside their agencies' normal operating parameters to support the management of equipment and facilities. Michigan DOT's experience with performance-based contracting and Pennsylvania DOT's multiple award bidding process are described below.

Short-Term Performance-Based Contracting (Michigan)

Background

Michigan DOT (MDOT) has several maintenance service contracts with local agencies. Transitioning to a direct forces maintenance operation managed and implemented by MDOT would take up to five years to become fully operational. When one contract agency failed to renew a maintenance service contract, the agency decided to try a performance-based contract addressing essential needs for approximately 600 lane miles of maintenance coverage and associated facilities.

Practice Description

With only one bidder, the contracting process was quick, and the contractor covered the needed maintenance for 600 lane miles and constructed two maintenance facilities to replace very old facilities. A new coordinator position oversaw the performance-based maintenance contract.

Challenges

Receiving only a single bid may have resulted in some inexperienced contractor staff and several changes in leadership.

MDOT intended the performance-based contract to be a short-term solution while the agency hired and trained staff. The five-year contract was only used for two to three years; the short-term nature without the potential for a longer-term contract created difficulties in the agency-contractor relationship.

Balancing performance-based requirements with urgent or emergency needs proved challenging, as did overall costs and impacts on other DOT maintenance areas during the facilities' buildup time.

Future Use

Going forward, MDOT will ideally retain a contracted agency until MDOT forces are up and running or may attempt to execute a longer-term performance-based contract. The respondent noted that short-term performance-based contracts may not be appropriate for other agencies.

Multiple Award Bidding (Pennsylvania)

Practice Description

Pennsylvania DOT's Central Office decided to implement multiple award bidding for plow trucks with the expectation of securing more build slots in a manufacturer's production schedule.

Benefits

While manufacturers' capacities can present some limitations, Pennsylvania DOT was able to procure more trucks from multiple manufacturers, in four different models instead of two.

Future Use

The multiple award bidding practice for plow trucks has become standard operating procedure for Pennsylvania DOT and has helped to keep equipment on intended replacement cycles. Other agencies can easily adopt a multiple award bidding practice with language changes in proposal requests.

2.4 Practice Topic: Materials

Four respondents described new materials practices in winter maintenance:

- **Mobile Detectors and Spreader Controllers to Control Salt Use** (*Massachusetts*). Integrate spreader controller with road weather sensor to regulate salt use based on temperature.
- **Direct Liquid Application (DLA) with Agricultural By-Products (ABP)** (*Michigan*). Test the effectiveness of a beet by-product used in DLA.
- **Slurry Application** (*North Dakota*). Try slurry for snow and ice control.
- **Slurry Application** (*Norwegian PRA*). Grind salt stones for a faster effect than using typical prewetting salt.

Details, including extended background on a Massachusetts DOT practice, are provided in the practice summaries below.

Mobile Detectors and Spreader Controllers to Control Salt Use (Massachusetts)

Background

Successful snow and ice control depends on the composition and amount of deicing material used. Traditionally, it has been generally assumed that more salt always leads to safer driving conditions on winter roads.

Excess salt, however, has resulted in chloride-impaired waterways and other environmental susceptibilities. Certain areas of Massachusetts are identified as *Reduced Salt Zones*, which require that half of the salt used is replaced with sand. While this practice has been employed for years, it is cumbersome and resource-intensive. Massachusetts DOT identified other disadvantages, such as sand quickly losing its angularity and thus its traction, requiring more frequent application. Additionally, this approach requires an increased frequency of catch basin sediment removal. A simpler reduced application rate of sodium chloride may suffice.

For several years, winter maintenance practitioners and salt spreader manufacturers have sought ways to conserve salt by linking its usage to actual weather and roadway conditions. Road condition sensing equipment attached behind the plow blade can support calibrating salt dispensation to actual roadway conditions and limit unnecessary salt usage. Additionally, prewetting salt, which is mandatory for the more than 1,000 contractors that help apply it to Massachusetts roadways, dissolves the salt crystals,

initiates the brining process and makes the salt sticky, preventing it from washing off onto the roadside or into waterways.

Practice Description

Massachusetts DOT worked with a road weather sensor manufacturer (Vaisala) and spreader controller vendor (Certified Power Solutions) to create a system that works in tandem with the plow blade scraping to optimize salt use.

The agency's initial project leveraged the temperature compensation function available on a SpreadSmart controller — as the temperature drops, salt dispensation increases and higher temperatures decrease salt use. The agency repurposed the temperature compensation function to consider grip instead of temperature:

- A weather sensor (MD30; other weather sensors use similar methodologies) installed behind the plow blade reads the post-scrape grip value, a two-digit decimal ranging from .15 (very poor grip) to .82 (perfect grip for driving).
- The weather sensor sends the grip value to the Certified Cirus SpreadSmart salt spreader controller that recognizes the grip level and adjusts the salt dispensation rate accordingly.

The concept and practice are simple: Poor grip leads to increased salt conveyor speed and strong grip leads to decreased salt dispensation. This advanced material spreader control could also be described as an "adaptive (feedback-based) spreader controller."

Benefits

Compared to a typical salt dispensation rate based on a defined pound-based level of salt usage per lane mile, the sensor system can save salt when road grip is strong.

Future Use

Massachusetts DOT is building on the described system to incorporate road weather forecasts. Beyond the real-time road condition as indicated by the sensor, understanding incoming road weather on a route for the next two to three hours may indicate an increased salt application.

Other agencies may consult with salt spreader controller vendors regarding how to correlate salt usage with something other than a vehicle's speed. The respondent is hopeful that the system can decrease salt usage for all jurisdictions that manage snow and ice. While road weather sensor and salt spreader manufacturers are producing effective equipment, it may take several years to become standard practice since most agencies infrequently purchase spreader controllers for their vehicles.

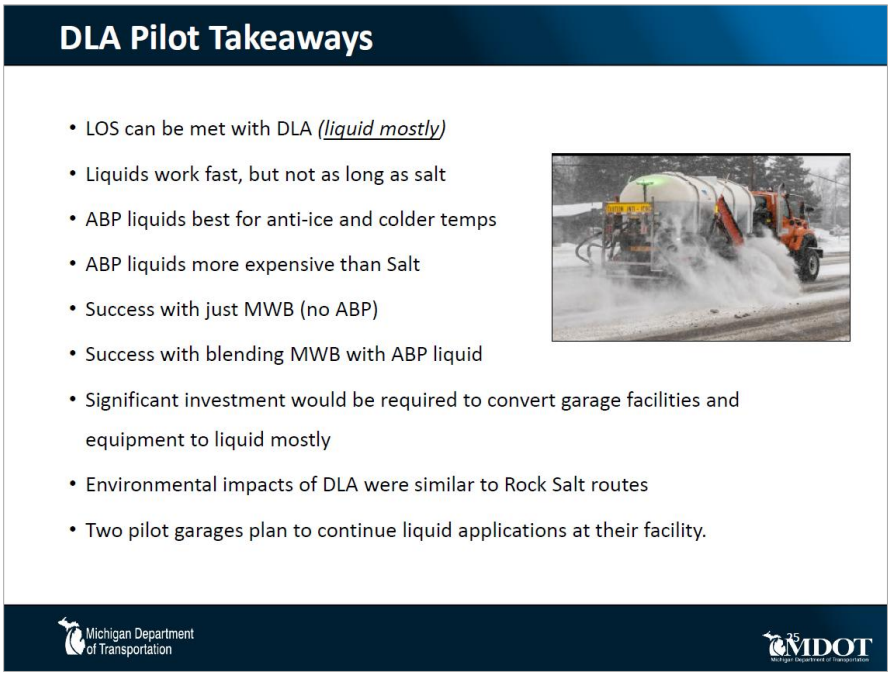
Related Resources

Development of a Salt Spreader Controller Program Using Machine-Sensed Roadway Weather Parameters, Massachusetts Department of Transportation, July 2024.
This project developed an automated system to optimize salt dispensation using mobile road weather information system (RWIS) sensors by developing hardware, software, a road surface condition algorithm and salt rate prediction model. Results showed the system can potentially decrease salt application by 34% and 37%, while maintaining or improving roadway grip.

SpreadSmart Rx: Electronic Spreader Control Systems, Certified Power Solutions, 2025.
From the brochure: Offering sophisticated technology such as temperature-controlled spreading, integrated load and rate management and Wi-Fi data transfer compatibility, the SpreadSmart Rx provides industry-leading precision and easy operation.

Direct Liquid Application (DLA) with Agricultural By-Products (ABP) (Michigan)

Topic	Description
Practice	Mandated by state statute, Michigan DOT's pilot project included three facilities operating both DLA-only routes using a beet by-product and traditional routes. Michigan DOT staff gathered data and observed results of these applications over five winters. Facilities committed to the pilot's implementation adjusted blending liquids to reduce cost and increase effectiveness.
Challenges	Field staff commitment and initial setup cost.
Benefits	Lower cost and less environmental impact were expected before the pilot.
Future Use	**Michigan DOT** issued an environmental cost–benefit report at the pilot's conclusion that identified reduced environmental impact but higher cost (Figure 2). While there may be an optimal time and place for DLA, the agency found liquid deicing and anti-icing — with or without an ABP — is not sufficient for certain storm events. DLA is not being pursued as a statewide practice.
Related Resources	**Assessment of Direct Liquid Application (DLA) with Use of Agricultural Byproducts (ABPs) for Winter Road Maintenance**, Michigan Department of Transportation, undated. This appropriations report, required by state statute, details background, process and study results. **Michigan DOT's Direct Liquid Application (DLA) Pilot**, Michigan Department of Transportation, *2025 Michigan Winter Operations Conference*, October 21, 2025. This presentation summarizes the pilot background, process and study results.



LOS = level of service

MWB = mineral well brine

Figure 2. Michigan DOT DLA Pilot Results

(*Source:* Michigan Department of Transportation; see slide 25 of the presentation cited above.)

Slurry Application (North Dakota)

Topic	Description
Practice	Dickinson and Bismarck districts are starting to use slurry for snow and ice control.
Challenges	Equipment funding.
Benefits	Faster-acting than brine, bare lanes can be reached within two hours when temperature is between 15°F and 30°F.
Future Use	Expected to be standard operating procedure in **North Dakota** within 10 years. **Other agencies** can start with a single district using a slurry truck, potentially retrofitting existing equipment, as North Dakota DOT did.

Slurry Application (Norwegian PRA)

Topic	Description
Practice	(The respondent noted that this is not a new idea and has been used throughout Norway for 20 years.) The PRA uses a grinder to decrease the size of salt stones to have a faster effect. Normally, the salt (sodium chloride) is simply prewetted with water.
Challenges	Not reported.
Benefits	Not reported.
Future Use	This slurry application method is standard practice in **Norway**, even though it is more expensive compared to typical prewetted salt. **Other agencies** can request instructions from PRA for grinding the salt stones.

2.5 Practice Topic: Training

Seven respondents described eight new training practices addressing equipment and general winter maintenance considerations.

Michigan and Pennsylvania DOTs reported on new work zone safety training practices that are included in the Safety and Outreach section of this report. Michigan DOT has also developed a winter operator school that all new employees attend but did not provide other details.

Details for the remaining eight practices are provided in the summaries below.

- **In-Person Snowplow Refresher** (*Arizona*). Provide in-person training as an alternative to online self-paced training.
- **Snow Operations Equipment Endorsement Training** (*Colorado*). Provide annual safety training covering snowplows, wing plows and tow plows.
- **Tailgate Training for Snow and Ice Contractors** (*Massachusetts*). Provide contractor training on front-end loaders, salt spreaders and liquid tankers, review protocols related to salt usage, and address environmental and operational concerns.
- **New Winter Operator Training** (*Nebraska HMS*). Educate new operators on policies, procedures and equipment.

- **Winter Maintenance Operations Testing** (*Norwegian PRA*). Ensure winter maintenance personnel are prepared by requiring them to pass a test before conducting winter maintenance operations.
- **Snowplow Simulator Training** (*Pennsylvania*). Provide newer operators the opportunities to "drive" using simulators under various conditions before getting behind the wheel of an actual truck.
- **Science of Winter Training** (*Pennsylvania*). Educate personnel on how winter materials work.
- **Winter Weather Training** (*Texas*). Improve winter response preparedness through training for maintenance supervisors and managers.

In-Person Snowplow Refresher (Arizona)

Topic	Description
Practice	Arizona DOT instituted annual in-person refresher training in response to feedback from plow drivers and as an alternative to online self-paced training.
Challenges	Training cost and operator travel.
Benefits	• Operators share experiences and knowledge. • Increased participation. • Received positive feedback.
Future Use	**Arizona DOT** continues to provide winter refresher training. **Other agencies** can evaluate current training methodologies and trainee expectations.
Related Resources	**Snowplow Simulators Help ADOT Prep for Winter Storms: Immersive Simulations Offer Operators Training for Icy, Snowy Roads**, Arizona Department of Transportation, December 2024. This news post describes a refresher course on the simulator series of winter readiness classes that cover safety protocols, the different parts of the snowplow, plowing techniques and more.

Snow Operations Equipment Endorsement Training (Colorado)

Topic	Description
Practice	Colorado DOT recently rolled out statewide annual training to obtain equipment endorsements for snow operations. The training, intended for completion before the winter season, covers snowplows, wing plows, tow plows and loaders. The agency also developed patrol plans for each snowplow crew to shift resources to areas of need.
Challenges	Safety training can be repetitive for more experienced operators who may become complacent.
Benefits	• Safer conditions exist for operators when they have knowledge of the equipment. • Safety training has reduced accidents and associated costs, particularly among newer employees.
Future Use	Equipment endorsement training for winter maintenance operators is standard operating procedure at **Colorado DOT.** **Other agencies** can develop training tailored to their specific needs.

Tailgate Training for Snow and Ice Contractors (Massachusetts)

Topic	Description
Practice	For more than 10 winter seasons, Tailgate Training for contractors has covered equipment to pretreat roadways with brine including front-end loaders, salt spreaders and liquid tankers. Massachusetts DOT: • Works with over 1,000 contractors for snow and ice removal. Tailgate Training reviews protocols related to salt usage, including environmental and operational concerns. • Offers a $300 training stipend to drivers holding a commercial driver's license who will operate a salt spreader, loader or tanker.
Challenges	Requires substantial planning and over $200,000 for approximately 20 sessions but is worth the effort.
Benefits	• The agency can refine snow and ice control concepts and contractors can share perspectives and information. • Provides new operators with awareness of environmental concerns, such as new or ongoing chloride-impaired streams or sodium-impaired reservoirs along plow routes, and why certain practices are needed in specific areas
Future Use	Tailgate Training is a standard operating practice at **Massachusetts DOT**. **Other agencies** relying on contractors for winter maintenance may provide similar annual training.
Related Resources	**Snow and Ice Vendor Information**, Massachusetts Department of Transportation, 2026. This website contains information for contractors who provide snow and ice removal services. **Snow and Ice Control Agreement 2025-2026**, Massachusetts Department of Transportation, September 2025. This agreement describes elements of Tailgate Training.

New Winter Operator Training (Nebraska HMS)

Topic	Description
Practice	New operator training addresses years of winter operations experience lost due to turnover.
Challenges	Scheduling when all operators and trainers can attend.
Benefits	• Educates new operators on policies and procedures and familiarizes them with the equipment in a comfortable environment. • Encourages safer winter operations with new operators who are less likely to become overwhelmed. • Provides for more efficient operations during winter events.
Future Use	**Nebraska DOT** provides new winter operator training annually. **Other agencies** can identify experienced operators exhibiting effective training practices and prepare them to conduct similar training.

Winter Maintenance Operations Testing (Norwegian PRA)

Topic	Description
Practice	Contractors' personnel participating in winter maintenance must pass a test taken at the driver and vehicle licensing office before conducting winter maintenance operations for the agency.
Challenges	Ensuring contractors prepare their personnel to pass the test.
Benefits	Not reported.
Future Use	Not reported.

Snowplow Simulator Training (Pennsylvania)

Topic	Description
Practice	Simulators provide newer operators the opportunity to "drive" a plow truck in various conditions before getting behind the wheel of an actual truck.
Challenges	Simulator costs and lack of simulator capacity to serve all operators.
Benefits	Improves situational awareness and reduces crashes.
Future Use	Not known if simulator training will become standard operating procedure at **Pennsylvania DOT**. **Other agencies** can consider the use of simulators that mimic the operation of vehicles used in winter maintenance.

Science of Winter Training (Pennsylvania)

The Pennsylvania DOT respondent highlighted the agency's "Science of Winter" training, which focuses on winter materials like brine and how they work. While the respondent did not provide additional information about the training, Figure 3 illustrates its concepts.

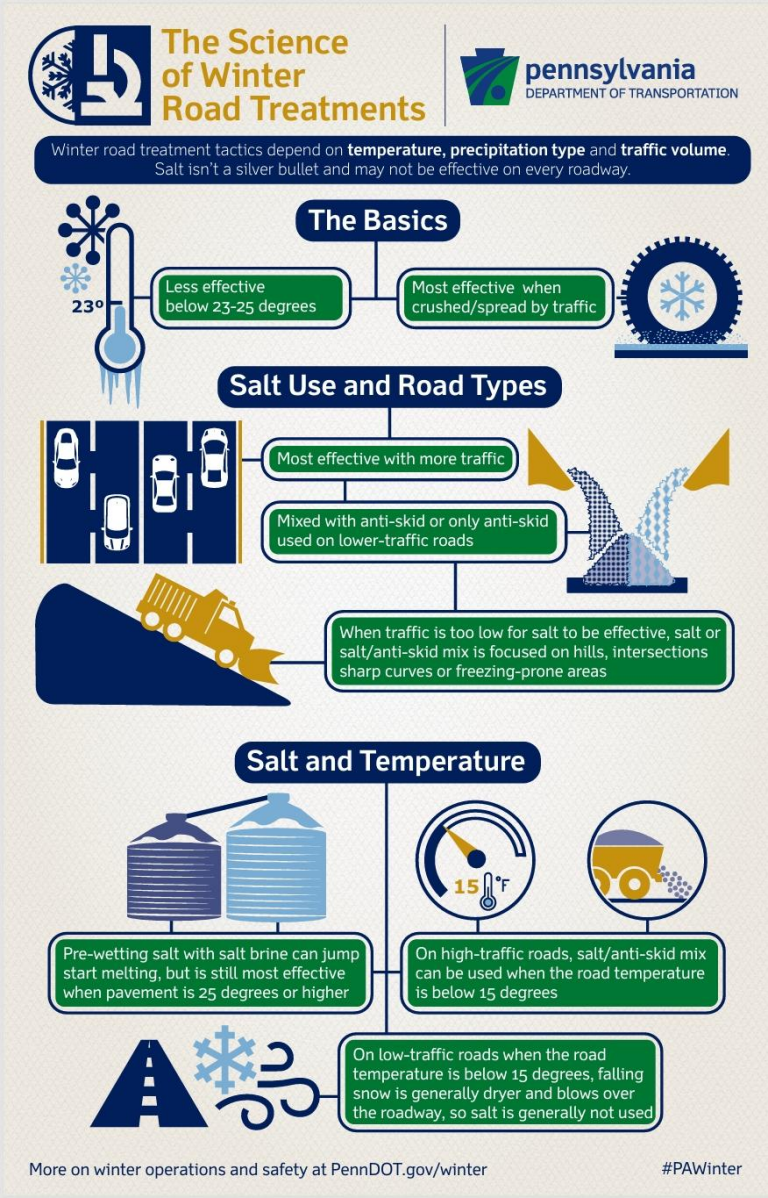


Figure 3. Pennsylvania DOT Infographic: The Science of Winter Road Treatments

(*Source*: Pennsylvania Department of Transportation.)

Winter Weather Training (Texas)

Topic	Description
Practice	Winter weather training for management and contractors started in the agency's northern and metro districts and was completed in all districts in 2025.
Challenges	Time commitment to train everyone. (The training program has taken two years.)
Benefits	The agency's Emergency Operations Center and Maintenance section supervisors and managers are better prepared for winter weather response.
Future Use	Training is ongoing at **Texas DOT**.

2.6 Practice Topic: Technology

Seven respondents described new technologies employed in winter maintenance:

- **Mobile Road Condition Sensor** (*Arizona*). Test the Vaisala Mobile Detector MD30 road surface data collector.
- **AVL and RWIS Program Expansion** (*Massachusetts*). Expand AVL and RWIS programs to better track salt distribution rates and weather parameters.
- **Electronic Driver Inspection Reports (EDIR)** (*Michigan*). Use EDIR to improve compliance with Driver Vehicle Inspection Reports (DVIR) and communication.
- **New AVL Provider** (*Nebraska HMS*). Test Samsara units in trucks.
- **Portable Maintenance Location Beacon** (*North Dakota*). Test iPin in maintenance vehicles and on arrow and message boards.
- **Weather Station Alternatives** (*Norwegian PRA*). Test small Internet of Things (IoT) weather stations that collect and transmit data on weather and road conditions.
- **Expanding AVL Systems** (*Pennsylvania*). Test turn-by-turn snow routes and dash cameras in plow truck AVL systems.

Details are provided in the practice summaries below.

Two respondents identified additional technology practices but did not provide any further details. *Arizona DOT* uses WX Horizon software in its RWIS and *North Dakota DOT* identified other technology-related practices:

- Apply integrated public alert and warning system (IPAWS) software for automated alerts on digital message signs.
- Use traffic control devices such as automated flagger assistance devices (AFADs), which are portable flagging stations, in new ways.
- Display signs on truck-mounted attenuator devices.
- Create digital twins to optimize variable speed limits.
- Employ GIS technology in inspection forms.
- Produce maintenance diaries and other new electronic forms on iPads.

Mobile Road Condition Sensor (Arizona)

Topic	Description
Practice	This pilot program launched in November 2025 to test the Vaisala Mobile Detector MD30, which collects and transmits data on road surface including grip, layer thicknesses and surface temperature.
Challenges	None reported.
Benefits	Provides real-time road surface data.
Future Use	**Arizona DOT** will gather data from other agencies using the MD30. The agency estimates that it will take two to three years to become standard practice.
Related Resource	Vaisala Mobile Detector MD30, Vaisala, 2024. This product spotlight describes a device that "helps fill road condition gaps in between stationary weather stations so you can see conditions across the entire network."

AVL and RWIS Program Expansion (Massachusetts)

Topic	Description
Practice	To better track where, when and which deicing and anti-icing treatments have occurred, Massachusetts DOT is expanding: • AVL to track location and telemetry of salt spreaders to better understand salt distribution rates, which rely heavily upon cargo box gate height settings and spreader calibrations. • RWIS to over 60 fixed locations and a few dozen mobile units installed in supervisor vehicles.
Challenges	• Contractors prefer not to be GPS-monitored. • Costly RWIS infrastructure maintenance.
Benefits	• Provides locations and speeds of hired vehicle assets and salt. • Offers a quick return on investment and high value in mobile RWIS units by providing information, including when roads are moist or starting to ice over.
Future Use	**Massachusetts DOT** will continue GPS tracking of salting vehicles and RWIS utilization to inform and support winter roadway maintenance. **Other states** can engage with their peers to learn more about GPS tracking and RWIS vendor information and facilitate the implementation of new practices.

Electronic Driver Inspection Reports (EDIR) (Michigan)

Topic	Description
Practice	Michigan DOT is using EDIR to improve compliance with Driver Vehicle Inspection Reports (DVIR) and communication between operators, lead workers, supervisors and mechanics (see Figure 4 on page 40). Four garages (10% of the agency's fleet) piloted EDIR during the winter of 2024/2025.
Challenges	• Unique reporting trees within each garage. • Email setup to reduce email overload. • Shift continuation and avoiding additional DVIR. • Information sharing between operators and shifts. • Requirement that tablet not leave cab of the truck. • Training. • Failure to close the communication loop back to the operator once a repair is made.

Benefits	• Improved DVIR document management:
	  ○ *DVIRs without defects* are customizable by each garage to distribute; standard practice is to batch and send once a day.
	  ○ *DVIRs with defects* are transmitted immediately.
	  ○ If a tablet fails, a hard copy of the DVIR is still available in all trucks.
	• Improved communication resulting in quicker repairs and reduced downtime.

Future Use	**Michigan DOT** fully implemented EDIR in the summer of 2025. **Other agencies** can consider support from AVL consultants to institute this practice.

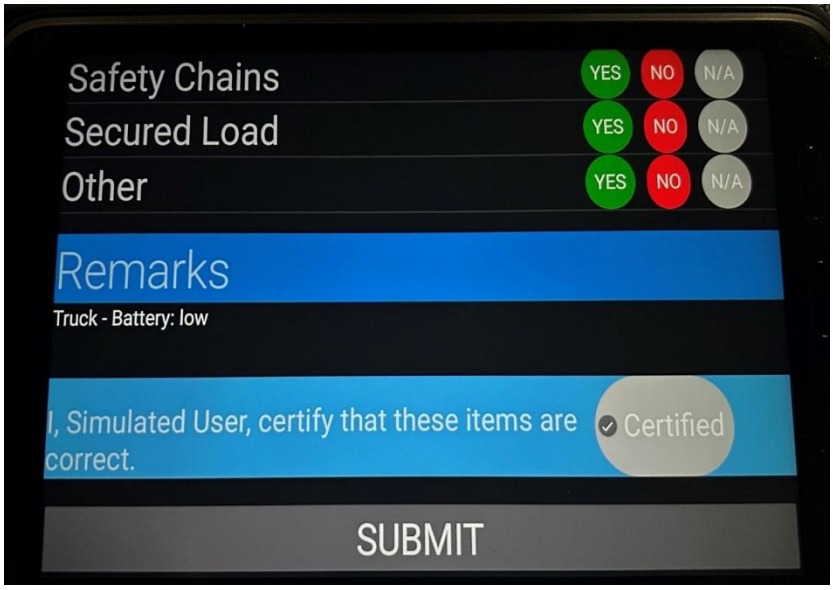


Figure 4. Screenshot of Michigan DOT's In-Cab Electronic DVIR

(*Source:* Michigan Department of Transportation.)

New AVL Provider (Nebraska HMS)

Topic	Description
Practice	Nebraska DOT installed Samsara units in a couple of trucks throughout the state.
Challenges	Using DOT maintenance forces to remove old AVL systems and install new ones.
Benefits	Not reported.
Future Use	While **Nebraska DOT** implemented the practice in winter 2025/2026, there are concerns that technology is regressing within the agency, as maintenance decision support system (MDSS) contracts were not renewed. District 7 plans to reinstitute MDSS. **Other agencies** can complete testing with AVL providers, working with technical support on any issues.
Related Resource	**What is Automatic Vehicle Location (AVL)?** Samsara, February 2026. This web page discusses the purpose of AVL and types of systems.

Portable Maintenance Location Beacon (North Dakota)

Topic	Description
Practice	North Dakota DOT tested iCone's ConnectedTech iPin in a few districts. The unit was placed in a maintenance vehicle or on an arrow or message board rather than installing it in a traffic cone, which can be hit. This portable device can "be used as a geometric guide to plot the start/end of a work zone or when strategically placed, multiple iPins can delineate the geolocation of your defined construction areas or work zones." Locations of maintenance work are displayed on 511 and travel maps via GPS (see Figure 5 on page 41).
Challenges	Funding.

Topic	Description
Benefits	Shows the traveling public where maintenance crews are on 511 and travel maps.
Future Use	This practice should be standard operating procedure for **North Dakota DOT** within two years. The agency is considering working with navigation companies to push out notifications. **Other agencies** can pilot iCone products, integrating them with 511 before launching the practice statewide.
Related Resource	iCone Products: IoR – Internet of Roadwork, undated. This web page describes a suite of technology devices that interface with existing traffic control equipment and communicate with the navigation systems of connected cars.

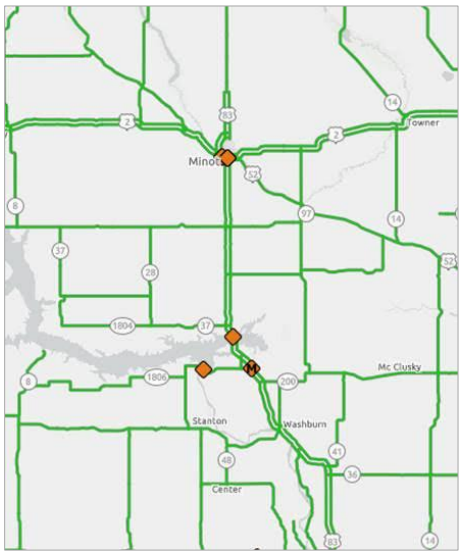


Figure 5. North Dakota DOT 511 Traffic Map Showing Maintenance Work Zones

(*Source:* North Dakota Department of Transportation.)

Weather Station Alternatives (Norwegian PRA)

Topic	Description
Practice	As an alternative to standard weather stations, the agency is testing smaller Internet of Things (IoT) weather stations that collect and transmit data on a variety of environmental conditions and optical sensors for determining road conditions.
Challenges	Not reported.
Benefits	Not reported.
Future Use	Not reported.

Expanding AVL Systems (Pennsylvania)

Topic	Description
Practice	Suggested by Pennsylvania DOT's Emergency/Incident Management Section and those overseeing winter operations, an in-process pilot effort is expanding AVL systems by implementing turn-by-turn snow routes in the cab and dash cameras in plow trucks.
Challenges	The turn-by-turn technology has been challenged by incorporating the agency's GIS maps into the platform and performing at desired levels.
Benefits	• Improved situational awareness and a decrease in accidents, damages and operator confusion. • Better plow route coverage.
Future Use	Expanding AVL systems will require two to five years to become standard practice for **Pennsylvania DOT**.

2.7 Practice Topic: Safety and Outreach

Seven respondents described nine new safety and outreach practices employed in winter maintenance:

- **Road Closure: Road Closure Plan** (*Nebraska HMS*). Use dynamic message boards for road closures in areas with the most traffic from interstate and bordering state road closures.
- **Road Closure: Text Interstate Closures During Winter Storms** (*South Dakota DO*). Develop a text-in notification service in which users receive text updates on road closures during winter events.
- **Roadway Information: 511 Traveler Information** (*Massachusetts*). Report color-coded roadway conditions through maintenance depots every two hours for inclusion on agency's 511 website.
- **Roadway Information: iPad Cameras for Snowplows** (*North Dakota*). Connect iPad cameras to 511 maps to increase public awareness of road conditions.
- **Roadway Information: Front-Facing Cameras on Plow Trucks** (*Pennsylvania*). Test PreCise MRM cameras to transmit images through a district's Force America/PreCise subscription service.
- **Safety Training: Tabletop Work Zone Safety Training** (*Michigan*). Provide training tailored to new hires based on regional traffic patterns and conditions.
- **Safety Training: Work Zone Training** (*Pennsylvania*). Develop work zone training to share with schools on how to properly travel through and near work zones.
- **Variable Speed Limits: Signs** (*Nebraska DOMM*). Employ variable speed limits (VSLs) to slow traffic when road conditions warrant.
- **Variable Speed Limits: Integrated VSL Messaging with RWIS** (*Pennsylvania*). Use RWIS data to create alerts for VSL messaging when roadway conditions warrant or other hazards are occurring.

Details are provided in the practice summaries below.

Two respondents identified but did not describe other new practices:

- Allowing counties and tribes to enter road restrictions and closures into the 511 traveler system to improve communication and prevent re-routing through third-party navigation apps (*South Dakota DO*).

- Working with equipment outfitters on a new system to identify all state vehicles/assets in a work zone and time their strobes to flash in unison to decrease motorists' visual distortion or the confusion night strobes can cause (*Massachusetts*).

Road Closure Plan (Nebraska HMS)

Topic	Description
Practice	Nebraska DOT is using dynamic message boards for road closures in areas with the most traffic from interstate and bordering state road closures. Messages board areas have ample room for cars and trucks to turn around if needed and roads can be closed quickly with barricades kept adjacent to message boards.
Challenges	Building pads for message boards.
Benefits	• Improved messaging to get timely, clear and concise information to the public. • Ability to inform the public of conditions and road closures at multiple junctions across District 7.
Future Use	**Other agencies** can consider locating message boards in areas with the most problematic road segments.

Text Interstate Closures During Winter Storms (South Dakota DO)

Topic	Description
Practice	South Dakota's 511 system requires a login and messaging is limited to auto-generated texts. A text-in notification service allows users to easily subscribe or unsubscribe to receive text updates on road closures during winter events.
Challenges	No interstate closures had occurred as of the survey response date to test the system.
Benefits	• Can communicate customizable messaging via text. • System has a very high read rate.
Future Use	The text-in system is standard operating procedure, along with traditional methods. **South Dakota DOT** expected the 3,000 initial subscribers to significantly increase when winter events began. **Other agencies** can develop similar systems.
Related Resource	**Text Notifications: Winter Interstate Closure Text Notifications**, South Dakota Department of Transportation, 2026. Scroll down on the web page for guidance on how to "[s]ubscribe to a free text-in service dedicated to keeping travelers informed of inclement weather-related closures on Interstate 90 and Interstate 29 in the state of South Dakota."

511 Traveler Information (Massachusetts)

Topic	Description
Practice	Conceived by a former Massachusetts DOT Transportation Systems Management and Operations director and supported by GIS staff to benefit the traveling public, any one of the more than 140 maintenance depots can report color-coded roadway conditions every two hours that are included on the state's Mass511 website.

Topic	Description
Challenges	• Covering all roads during active snowfall. • Potential two-hour gap between a road condition report and the 511 user reading it.
Benefits	Information supports public travel planning.
Future Use	**Massachusetts DOT** will continue operating the system during snow and ice winter roadway maintenance. **Other agencies** can emulate this road condition reporting practice.

iPad Cameras for Snowplows (North Dakota)

Topic	Description
Practice	North Dakota DOT connected iPad cameras installed as front-facing cameras in snowplows to the agency's 511 map to increase public awareness of road conditions.
Challenges	Funding.
Benefits	Prevents the public from road travel during blizzards.
Future Use	The practice will be standard operating procedure for **North Dakota DOT** in three years. **Other agencies** can connect iPad cameras to 511 systems.

Front-Facing Cameras on Plow Trucks (Pennsylvania)

Topic	Description
Practice	Pennsylvania DOT tested PreCise MRM cameras to transmit images through the Force America/PreCise subscription service in District 2.
Challenges	• Choosing the right photos to illustrate, for example, why a particular road segment is closed and avoid showing inactive trucks, as there would be no accompanying explanation. • Developing an image retention policy for manageable records requests.
Benefits	• Helps to show the traveling public why roads are closed or in poor condition due to winter storms, which may encourage compliance with *road closure* or *no unnecessary travel* advisories. • Assists district staff with resource planning during storms.
Future Use	**Pennsylvania DOT's** District 2 reported positive pilot results except in areas of poor coverage and is purchasing subscriptions and cameras for all plow trucks. The agency's traffic management centers (TMCs) plan to use more of these images during the winter season by posting them on an outward-facing TMC Live website. The camera system could be standard operating procedure in three to five years.
Related Resource	**PreCise: Solutions**, PreCise MRM, LLC, 2026. *From the website:* PreCise MRM makes fleet management easy by providing solutions to your everyday obstacles. Increase your productivity and make more informed decision through implementation of our AVL (Automatic Vehicle Locators).

Tabletop Work Zone Safety Training (Michigan)

Topic	Description
Practice	Safety training is provided by Michigan DOT work zone staff and tailored to new hires in all regions based on different traffic patterns and conditions (Figure 6).
Challenges	• Varying regional traffic patterns and conditions require customizing training to best suit each region. • Agency work zone units are focused on construction standards and lack a comprehensive understanding of maintenance issues.
Benefits	Provides better understanding of safety requirements and how to adjust for different scenarios and physical features of the environment.
Future Use	**Michigan DOT** employees find the safety training valuable and suggest offering it more widely and making it mandatory for new hires. The tabletop materials are available to each region to encourage training (Figure 7).

Figure 6. Michigan DOT Tabletop Training Class

(*Source:* Michigan Department of Transportation.)

Figure 7. Michigan DOT Tabletop Training Materials

(*Source:* Michigan Department of Transportation.)

Work Zone Training (Pennsylvania)

Topic	Description
Practice	Pennsylvania DOT and Pennsylvania Turnpike collaborated on an updated work zone training to share with schools on how to properly travel through and near work zones.

Topic	Description
Challenges	Not reported.
Benefits	Reduces crashes and injuries.
Future Use	**Pennsylvania Department of Education** can include work zone training in their curriculum.

Variable Speed Limit Signs (Nebraska DOMM)

Topic	Description
Practice	Nebraska DOT tried using VSL signs to slow traffic consistent with road conditions.
Challenges	• No regulatory authority to mandate. • Cost. • Operational breakdowns. • Determining appropriate speeds for conditions to ensure effective use.
Benefits	None reported.
Future Use	**Nebraska DOT** will not use VSL as a standard operating procedure and does not recommend the practice for **other agencies**.

Variable Speed Limits and Integrated Messaging with RWIS *(*Pennsylvania)

Topic	Description
Practice	Pennsylvania DOT is: • Expanding the use of VSL on multiple interstates to reduce speed during inclement weather. • Employing integrated messaging from RWIS data to generate an alert sent to local TMCs to notify travelers when whiteout conditions or other hazards are occurring.
Challenges	• Costs. • Determining device locations.
Benefits	Reduces crashes and injuries.
Future Use	**Pennsylvania DOT** continues to test VSL and RWIS message integration. These practices could become standard operating procedure in two to five years.

2.8 Emerging Technologies and Practices

The survey defined emerging technologies and practices as those that are not currently market-ready but expected to be publicly available within the next five years. Respondents reported varied interests such as using floating car data, which refers to information collected from vehicle sensors including position, vehicle traction and road surface conditions, and weather (*Norwegian PRA*) and a general need to get messages to the public while discouraging phone use while driving (*Pennsylvania*).

Other survey responses identifying emerging technologies and practices are summarized below in five topic areas, followed by a presentation of the reported challenges involved in exploring new technologies:

- Artificial intelligence
- Forecasting
- Materials practices
- Equipment
- Training

Artificial Intelligence

Some respondents noted a general interest in using artificial intelligence (AI) for planning (*Arizona* and *Pennsylvania*) and technology practices (*Arizona* and *North Dakota*). Other reported uses for which emerging AI technologies could help included:

- Assessing road condition from camera images (*South Dakota Ops*) and automating road condition updates (*South Dakota DO*).
- Road closure assistance (*Massachusetts*).
- Snowplow routing (*Pennsylvania*).
- Weather forecasting (*Pennsylvania* and *Texas*). Texas DOT is working closely with the private sector on this potential use of AI.

Forecasting

Two respondents indicated the importance of improved tools for forecasting pavement condition, including for road salting in Norway.

The Nebraska HMS respondent commented that winter maintenance staff does "a good job at providing the best service in winter operations," noting that pavement forecasting tools resulted in increased efficiency in using time and resources and better service to the public. Nebraska DOT previously used a MDSS system that is no longer available to the agency, and the respondent identified concerns about moving forward without this forecasting tool.

Materials Practices

Four agencies are seeking increased efficiency in materials usage. While Michigan DOT is interested in automated salt inventory control, North Dakota DOT indicated a general interest in emerging practices for "optimal use of materials." Similarly, Pennsylvania DOT is hoping for cost-effective alternatives.

North Dakota DOT's goal of efficient operations and materials use was illustrated by an example described by the respondent:

> We did some research over [six] years to see how long silane bridge deck sealer lasts, as the manufacturer told us that we didn't have to keep reapplying the product. Our current maintenance practice is to reapply every five years as the product's longevity was uncertain, and we want to avoid damaging the bridge. The research showed that the silane remained in a concrete test pad, so now we could potentially seal the bridge deck during construction and not use our maintenance forces to reapply the product.

> We are trying something new every week in maintenance to increase efficiency. This is an example of how North Dakota DOT maintenance is leading the way to new maintenance practices in efficient operations.
>
> *— North Dakota DOT respondent*

Equipment

Three state DOTs identified new equipment of interest:

- Improved wash bays and best practices for winter equipment (*Pennsylvania*).
- Different lighting techniques for winter operations vehicles (*Wyoming*).
- Variable message signs identifying road conditions, potentially used with an AI-assisted road closure process (*Massachusetts*).

Training

Two respondents cited elements of training as emerging practices of interest: driver simulator effectiveness (*Michigan*) and enhanced, hands-on operator training (*Pennsylvania*).

Challenges to Exploring Emerging Technologies

Table 2 summarizes the challenges or barriers to exploring or testing emerging technologies reported by respondents. Following the table is a more detailed discussion from the Massachusetts DOT respondent addressing the lack of trust in technology.

Table 2. Challenges or Barriers to Exploration of Emerging Technologies

Challenge or Barrier	Respondent and Description
Bureaucracy	*Arizona*. Standardized practices. *North Dakota*. Multiple levels of approval will cause very slow progress.
Costs	*Arizona.* *Columbus, Ohio.* Funding. *South Dakota Ops*. Budget restraints.
Data or IT Issues	*Michigan*. Data security. *Pennsylvania*. IT standards present challenges for some technologies.
Leadership, Staff or Legislative Support	*Columbus, Ohio.* Buy-in from the top to the drivers in an agency. *South Dakota Ops*. Buy-in. Wyoming. Will likely need legislation.
Technology Challenges	*Columbus, Ohio.* Connecting hardware and software from different vendors. *Massachusetts*. Trust in technology; see below.

Trust in Technology

The Massachusetts DOT respondent provided an example of the implications of a lack of trust in or reliance on technology:

> An example of the ideal use of technology is a variable message sign connected to an RWIS that displays a message advising of a dangerous or slick roadway condition ahead. A motorist sees the message and slows down.
>
> In some places, there is a disconnect in the field because staff may not trust in, or rely on, the technology. For example, there is likely a higher risk of deadly crashes in a fog-prone valley. Visibility sensors can identify when it may be unsafe to drive through this stretch of roadway and, in real time, trigger a lighted gate to flash and lower, indicating the road is closed. DOT staff could then be called out to come to the location and verify the condition. Unnecessary delays are possible if the trigger turns out to be a false alarm.
>
> The current response to such a scenario is this: A dangerous condition is identified and a roadway supervisor is dispatched to verify the condition. If verified, the gate is lowered and the road is closed to prevent accidents.
>
> The respondent would rather see the gate lowered immediately and allow the condition to be manually verified. As he noted, "We all have a few minutes for this scenario to unfold more safely."

2.9 Winter Maintenance Challenges and Strategies

Survey respondents reported challenges their winter maintenance programs are experiencing today or may encounter in the next five years. These include general concerns such as a lack of competence in winter maintenance and drivers expecting bare roads in any weather condition (*Norwegian PRA*) and distracted drivers (*Colorado*). Another respondent indicated that buy-in is necessary from employees and the public, adding that "folks don't seem to want to take ownership anymore" (*Pennsylvania*).

Other challenges are organized into five topic areas:

- Budgets and costs
- Equipment and materials
- Staffing
- Technology
- Changing traffic and climate conditions

Following the discussion of these challenges is a summary of agency responses to challenges and recommendations for other agencies seeking new practices.

Budgets and Costs

Ten state DOTs cited financial resources as a primary challenge for winter maintenance programs. Some cited general budget and funding concerns (*Arizona, Kentucky, North Dakota* and *Oregon*) or the need for additional staff (*Massachusetts*).

Rising costs of equipment and materials are challenging for several respondents (*Colorado, Pennsylvania* and *Texas*). Other concerns with rising costs included:

- Maintaining aging facilities (*Wyoming*).

- Updating equipment (*Nebraska DOMM*).
- Purchasing the agency's own winter maintenance equipment (*Massachusetts*).
- Not purchasing any new equipment this biennium due to lack of funding will set the agency back significantly in the long term (*Oregon*).

The North Dakota DOT respondent also cited a lack of legislative support as a concern.

Equipment and Materials

In addition to equipment costs, respondents reported concerns regarding equipment breaking down (*Colorado*) and snowplow hits (*South Dakota Ops*). Wyoming DOT reported that emissions systems can be particularly problematic in keeping newer equipment operational. While Texas DOT's equipment is in very good condition overall, increased complexity of vehicle electrical systems causes some concern and as trucks get larger, more space is needed.

Two respondents identified challenges related to salt: Kentucky DOT has had to switch to a new product for liquid prewetting of salt, and Michigan DOT struggles with consistent liquid use and the salt reporting process.

Staffing

Twelve respondents cited staffing issues as a challenge to their winter maintenance programs. Some identified staffing generally as a challenge (*Arizona*, *Oregon* and *South Dakota Ops*).

The South Dakota DOT Ops respondent noted that the agency can't compete with outside pay. The South Dakota DO respondent added that addressing needs for 24-hour operations in critical locations and updating 511 road condition notices during overnight hours is challenging. (South Dakota is not a 24-hour operations state.) Similarly, in North Dakota, the time needed for implementation can be an issue.

Oregon DOT has had to lay off staff. Unable to readily fill vacancies, the respondent noted that it will likely take a decade or two to improve morale and attract well-qualified employees. Massachusetts DOT's high reliance (85%) on contractors for roadway snow and ice mitigation creates challenges.

Other staffing challenges included:

- Retention (*Colorado, Kentucky, Michigan, Nebraska DOMM* and *Nebraska HMS,* and *Wyoming*). The Nebraska HMS respondent noted that the turnover leaves the agency with inexperienced operators.
- Hiring in general (*Kentucky, Texas*, *Wyoming* and *Norwegian PRA*). Texas DOT's hiring issues are agencywide and at Norwegian PRA, it is hard to find contractors with skilled winter maintenance personnel.
- Recruiting for specific positions. Drivers for winter maintenance operations are in short supply everywhere (*Massachusetts*), and turnover and shortages are impacting equipment operators and mechanics (*Pennsylvania*).

Technology

Several agencies reported challenges with technology, including implementation (*Arizona*), technology not being utilized (*Nebraska HMS*) and keeping current on latest technologies (*Pennsylvania*). Conversely, the South Dakota DOT Ops respondent noted that too much technology in trucks causes driver safety issues, and the Arizona DOT respondent identified self-driving cars as a current or future challenge.

Other technology challenges:

- Updating message board and closure gate technologies (*Nebraska DOMM*).
- Increase in stranded vehicles needing to be rescued due to third-party navigation apps (*South Dakota DO*).
- Lack of cellular technology in rural areas that results in the loss of AVL and maintenance data used to track winter performance (*South Dakota Ops*).

Changing Traffic and Climate Conditions

Several agencies highlighted challenges associated with changing traffic and climate conditions:

Traffic. Colorado DOT reported deteriorating roads as a challenge and increasing traffic volumes are a challenge for Arizona and Texas DOTs; trailers with low accessibility create traffic issues on inclines in Norway. The Texas DOT respondent noted that tremendous growth over the last decade has increased traffic in both urban and rural areas, and some new residents come from areas that may not have ice and snow.

Climate. Changing weather patterns are challenging for three agencies' winter maintenance programs:

- In Massachusetts, variable winter weather leads to variable regional equipment needs, which can translate into uncertain revenue expectations for contractors and impact their desire to do this work in the future. Environmental degradation is also an ongoing risk.
- Norway's climate changes include increased heavy snowfall, wind and rapid temperature changes.
- Weather systems are ever-changing in Texas. The state has experienced extreme conditions in the last five years. During this time, the agency has identified issues with weather forecast reliability.

Agency Responses to Challenges

Respondents provided a variety of perspectives regarding general and specific agency support for meeting winter maintenance program challenges. While some agencies indicated doubts as to agency capacity to provide needed support (*Norwegian PRA, Oregon* and *Wyoming*), others indicated their agencies are always looking for solutions to challenges (*Pennsylvania*) or reported general agency support, with one agency characterized as "open to changes and adapting to new technologies" (*Colorado*).

Other ways agencies provide support to winter maintenance programs are summarized in Table 3.

Table 3. Agency Strategies to Support Winter Maintenance Programs

Strategy	Respondent and Description
Compensation	*Massachusetts*. Guaranteed contractor hours (see the description following the table). *South Dakota Ops*. Executive team exploring different incentives and pay increases for recruitment and retention.
Employee Training	*Kentucky.* Works to establish programs to boost personnel training. *Michigan.* Winter operator school for all new employees. *Nebraska HMS*. Making progress in training all new operators.
Funding	*Arizona. P*rovides financial support for new practices. *Kentucky*. Fights for funding.
Infrastructure and Equipment	*South Dakota DO.* Continual improvements to traveler information through SD511, website and social media. *South Dakota Ops:* • Governor's Office working on telecommunications improvements in rural areas. • Installing blue lights to the left rear of snowplows to reduce the number of hits.
Trying New Ideas/Continuous Improvement	*Arizona.* Continuously reviewing winter operation practices and listening to feedback. *Nebraska DOMM*. Planned technology projects. *North Dakota*. "We do many new things every year!" *Texas*. Forward-looking teams implement new ideas and technologies.

Guaranteed Contractor Hours (Massachusetts)

Challenge

Massachusetts has characteristics that produce abundant snow in the west and not as much near the coast. The comparatively low cost of living in the western part of the state with the higher cost in coastal regions has the impact of making the market self-supporting in the west, while the agency struggles to find available contractors in the east, where more people live.

Traditionally, the agency pays hourly rates based on work performed — no snow means no work. As a result, contractors leave the winter maintenance program because as weather warms — even for just a few seasons — it becomes too risky to spend money readying equipment that might not get used.

Potential Solution

Massachusetts DOT is considering a *Guaranteed Hours* concept that promises a certain number of hours per equipment type (loader, salt spreader, plow or tanker). Ten percent of the guaranteed hours would be paid for each of the first 10 pay periods, unless snowfall creates actual service hours. Agency leaders believe that guaranteed income for contractors over the first 10 pay periods will help retain drivers for their equipment. As the respondent noted, "If that Contractor doesn't have money in his pocket to put in the driver's pocket simply to retain him, what's the guarantee that the driver will be available come snowfall?"

The agency also recognizes the need to provide winter maintenance services for a larger percentage of the roads than the 15% it currently maintains.

Recommendations for Agencies Seeking New Practices

Summarized below are the recommendations respondents offered to other agencies seeking to implement new practices organized into five topic areas:

- Collaboration
- Funding
- Research and planning
- Training and safety

Collaboration

Table 4 summarizes the collaborative actions respondents recommended to help to advance new practices.

Table 4. Recommended Collaborative Activities

Activity	Respondent and Description
Establish New Collaborative Practices	*Colorado*. Conduct pre- and post-storm meetings with stakeholders to develop relationships and effectively manage storms together to provide the best service for the traveling public.
Identify and Adapt Other Agency Practices	*Michigan.* Seek out other agencies and professionals who have attempted or implemented a practice of interest. *Nebraska DOMM.* Explore what other agencies and states are doing and how your agency can adapt new practices.
Investigate Previous Clear Roads Research	*Massachusetts*. Examine the research available on the Clear Roads website that may be unfamiliar and ask other members questions about the application of this research.
Reach Out to Other States, Agencies or Municipalities	*Kentucky*. Consult with other state agencies on similar practices. *Pennsylvania*. Reach out to other states to understand any new practices they are working on. *Texas*. Look to other DOTs or municipalities to determine if they have successfully implemented practices.
Seek Private Sector Collaboration	*Norwegian PRA*. Involve contractors and suppliers early in any process.

Activity	Respondent and Description
Seek Internal Collaboration	*Columbus, Ohio.* Seek essential buy-in from senior management. *Michigan*. Use internal resources, such as identifying subject matter experts for some of the "heavy lifting." *Pennsylvania*. Gather feedback from field personnel on their needs and beneficial new ideas.

Funding

Three agencies offered suggestions related to funding. While the South Dakota Ops respondent noted the importance of reviewing the costs and benefits of a proposed new practice, the Nebraska DOMM DOT and Columbus, Ohio, respondents suggested considering seeking grants or other programs, or partnering with other agencies to fund ideas.

Research and Planning

Respondents recommended research as a general practice (*Kentucky* and *North Dakota*) and research into specific topics such as mobile friction for winter operations (*Colorado*), and suggested fully understanding a technology to optimize its use (*Nebraska HMS*).

Several recommendations related to understanding issues through research, and identifying needs and resources as part of a larger planning effort:

- Understand the benefits of a proposed practice to the agency, such as reduced costs, reduced cycle times, improved environmental compliance or improved safety of employees and the public (*Columbus, Ohio*).
- Explore different solutions using existing capabilities. For example, if salt spreaders do not include prewetting equipment, prewet material at the stockpile before loading trucks. The next-best-thing always beats nothing (*Massachusetts*).
- Inventory existing capabilities and data required to implement a new practice (*Massachusetts*).
- Examine the new practice from all angles: executive, planning, finance, operations and communication (*Michigan*).
- Investigate and address problems as they arise when implementing a new practice rather than assume the practice is not successful (*Nebraska HMS*).

Training and Safety

Three respondents recommended a focus on training or safety:

- *Colorado DOT*. Train operators to manage storms with forecasting and by understanding material temperature parameters. The agency's Winter Maintenance Frequently Asked Questions provides both general and technical answers to questions about winter road treatments, snow removal and road conditions.
- *Kentucky DOT*. Ensure employees are trained on implementation methods for new practices.
- *Texas DOT*. Provide training to internal staff and external partners. In general, keep employee safety at the forefront of any new practice. For example, when new slide-in sanders or brine units were delivered without self-supporting legs, this minor oversight on the procurement

checklist could have been a major issue for employees in the field. Now all units come with support legs. As the respondent noted, "Training is the key to safety."

> Always be open to new ideas to evolve as an agency. We can get better in everything that we do as long as we continue to research and investigate new ideas.
>
> — *Nebraska HMS respondent*

2.10 Lessons Learned from Implementing New Practices

Responding agencies described a variety of lessons learned when implementing new practices across a range of topics. Lessons learned that can become best practices are organized around common themes and summarized in Table 5.

Table 5. Lessons Learned from Implementing New Practices

Theme	Respondent and Description
Collaboration and Communication	*Kentucky.* Maintain good, clear communication between the roadway weather team and agency leadership. *Michigan*. When trying or piloting new practices*:* • Identify the right stakeholders and communicate their roles, agency expectations and decisions with rationales. • Work with smaller groups. *North Dakota*: • The technology is usually 80-90% complete; work with the correct partner on the remaining 10-20%. • An agency likely has many people who support the idea; find those who are aligned. *Norwegian PRA*. Involve contractors early in the process.
Internal and External Education	*Kentucky:* • Acknowledge the importance of educating leadership and district staff when implementing change. • Ensure that the public is educated on new policies. *Massachusetts.* Stay on top of environmental and other science relevant to operations. *Nebraska HMS.* Recognize that ensuring leadership understanding and clearly articulating the "whys and hows" leads to operator buy-in and a greater likelihood of success of systems and technologies. *Pennsylvania.* Continually update winter trainings with relevant materials. *Texas.* Keep training at the forefront: • Extend training opportunities to partners. • Provide pre-winter statewide winter weather workshops. • Enhance partnerships with neighboring DOTs by holding district or regional winter weather meetings and inviting the agency's counterparts over the state border to participate.

Theme	Respondent and Description
Operational and Administrative Considerations	*Colorado.* Thoroughly test new practices with a few patrols before widely implementing. *Massachusetts:* • Always consider the environmental impacts of the winter maintenance program, not only when identified by regulators. • Practice what you preach. For example, if contractors are required to prewet the salt, agency staff should be prewetting too. • Be ready every autumn despite limited snow in previous years. *North Dakota.* Start small. *Norwegian PRA*. Update contracts with new text incorporating new technology or practices.
Specific Practices	*Colorado:* • Apply bond breaker when storms begin to conserve material, equipment and overtime. This practice also provides shorter asphalt regain time. • Employ mobile friction sensors. If used properly, they pay for themselves quickly by reducing material use. *Pennsylvania:* • Use winter event vehicle restrictions to reduce crashes and limit the interstate closures required to clear them. The agency's commercial motor vehicle restrictions are issued in tiers based on the severity of the winter weather event. • Update AVL technology for garage use and vehicle diagnostics. *South Dakota DO.* Allow local counties and tribes to enter restrictions and closures through the state's 511 system. *South Dakota Ops*. Implement text-in service for interstate closures. *Texas*. Prioritize employee safety. Consider offering new personal protective equipment such as heavy winter bib overalls to complement winter coats. This practice has had great results.

3 Examining the Literature

3.1 Introduction

A literature search examined in-process and published domestic research and related resources to identify a sampling of resources addressing recent or leading-edge practices in winter maintenance in the six categories used to organize Clear Roads research:

- Planning
- Equipment (including facilities)
- Materials
- Training
- Technology
- Safety (including outreach)

The compilation of citations below begins with Clear Roads research and publications addressing more than one research category.

3.2 Clear Roads Research

Research in Progress: Synthesis: Predictive Methods to Update Road Condition Reporting, Clear Roads Pooled Fund Study, start date: October 2025; expected completion date: March 2026.
https://www.clearroads.org/project/24-s1/
From the objective: This synthesis will gather information on how state DOTs collect, report and share information about winter road conditions with the public; whether states have explored, tested or implemented automations, AI or predictive modeling to update traveler information systems; and states' experiences with these advanced technologies, including their accuracy, reliability and implementation challenges.

Research in Progress: Synthesis: Update on the Status of AVL/GPS for Winter Operations, Clear Roads Pooled Fund Study, start date: October 2025; expected completion date: April 2026.
https://www.clearroads.org/project/24-s3/
From the objective: To survey and compile information on the various AVL systems including what data providers are able to produce and on which controllers. This should include what information is able to be tracked; application rates of various materials, both solids and liquids; what level of accuracy is the material usage; and depending on the calibration of the spreader, is the data accurate enough for inventory purposes.

Integrating Advanced Technologies into Winter Operations Decisions, Clear Roads Pooled Fund Study, December 2020.
https://www.clearroads.org/project/17-01/
From the project results page: This project developed a user-friendly guide to the technologies available for winter maintenance operations. The guide outlines what these technologies measure, describes how to integrate them into a successful winter maintenance operations strategy, and provides recommendations on how to incorporate future technologies into the strategy.

From the final report's abstract: This report summarizes the state of the practice in the application of advanced technologies to winter road maintenance operations. Information was captured through a combination of literature search, surveys and interviews with key stakeholders. Several promising technologies were identified as areas of interest. These areas include connected automated vehicles, mobile sensor systems, driver assistance systems, enhanced/next generation MDSS, "big data"

platforms, data visualization and video analytics. Use cases for each technology are detailed along with recommendations for potential deployments in both near term and over a five-year planning horizon.

3.3 Multiple Research Categories

"The Innovative Future of Winter Maintenance," Anthony Davis, *Highways Today*, November 18, 2025.
https://highways.today/2025/11/18/innovative-winter-maintenance/
From the article: Winter maintenance has always been a demanding responsibility, yet recent years have amplified the strain on road authorities. Climate volatility, ageing transport networks and rising public expectations have created an environment in which traditional, reactive maintenance models simply cannot keep pace. Departments are now tasked with protecting mobility and safety under increasingly complex conditions while balancing shrinking budgets and persistent infrastructure deterioration.

A transition from reactive work to strategic, intelligence-led management is becoming essential. Modern winter operations require actionable data, integrated technology and the ability to anticipate problems before they escalate. This shift is being accelerated by advances in geospatial intelligence, artificial intelligence, and asset lifecycle management platforms that bring clarity, precision and efficiency to one of the toughest jobs in public infrastructure.

"Research Radar: Advancements in Winter Maintenance," MnDOT Research and Innovation, Minnesota Department of Transportation, December 2024.
https://www.youtube.com/watch?v=IiU1JXD-zwA
This video features three research projects that use new technologies and approaches to enhance winter maintenance capabilities and improve traffic safety:

- Snowplow Driver Assist System
- Using AVL/GPS Telematics to Optimize Snowplowing
- Human-Centered Testing of Rear-Facing Display to Reduce Vehicle Collisions with Snowplows

"Managing Severe Storms and Environmental Impacts," Webinar, Transportation Research Board (TRB) Road Weather Committee and Winter Maintenance Committee, 2022.
https://www.nationalacademies.org/events/667
This TRB webinar includes three presentations:

- Predicting Road Weather Emergencies: Advancements in Storm Forecasting and Risk Communication, Chad Hahn, National Weather Service
- The Loss of Salt from the Road Surface – A Coin with Two Sides: Environmental Implications, Göran Blomqvist, VTI (Swedish National Road and Transport Research Institute)
- Leveraging Technology for Better Materials Management and Cost Savings at MassDOT, Mark Goldstein, Massachusetts DOT

3.4 Planning

Developing Snow Performance Measures for Public Information, Shailendra Khanal and Patrick A. Singleton, Utah Department of Transportation, July 2025.
https://drive.google.com/file/d/1QPzPcS5Im_MeKySFSIV-SJrA_FlqDlrJ/view
From the abstract: This research examines public satisfaction with winter road maintenance (WRM) and transportation behaviors during snow events in Utah, with the goal of informing more transparent, responsive, and data-driven strategies and public communication. A detailed online survey of 568 residents across six distinct geographic zones captured public perceptions following two major winter

storms in 2024. Survey responses were integrated with data from UDOT's Road Weather Information System (RWIS) to analyze how subjective experiences aligned with objective storm metrics. Findings from ordered and binary logit models reveal that satisfaction with WRM is not strongly influenced by perceived snowfall or storm intensity, but rather by personal and household factors. Satisfaction tended to be higher among younger-to-middle-aged adults, men, students, non-workers and those in middle-income households. Travel behavior was shaped by both demographic factors and storm timing, with most respondents opting for personal vehicles — highlighting the continued importance of reliable road maintenance. Active and public transportation modes were used infrequently, often constrained by environmental conditions and infrastructure access. Importantly, perceived storm severity largely aligned with RWIS data, validating the public's awareness and reinforcing the value of integrating public sentiment into WRM evaluation dashboards. Also, people were most satisfied with WRM by UDOT and on major roads and highways; the facilities that were also prioritized by respondents. This study offers actionable recommendations to UDOT, including prioritizing critical areas, coordinating with other agencies, integrating advanced technologies, and continuing to enhance communications and public feedback mechanisms to reflect both lived experiences and operational effectiveness.

Winter Severity Index with Winter Maintenance Expenses and Material Usage, Ali Zockaie, Ardeshir Fadaei, Farish Jazlan, Hamid Mozafari, Mehrnaz Ghamami, Timothy Gates, Peter Savolainen and Jeffrey Andresen, Michigan Department of Transportation, July 2025.
https://www.michigan.gov/mdot/-/media/Project/Websites/MDOT/Programs/Research-Administration/Final-Reports/SPR-1755-Report.pdf
From the executive summary: Winter road maintenance in Michigan presents significant challenges due to the state's complex climate, geographic diversity and extensive road network. The Michigan Department of Transportation (MDOT) annually invests substantial resources — particularly in salt, sand and liquid deicers — to ensure safe travel conditions during winter months. Recently, MDOT has introduced a Weather Severity Index (WSI) to assess and compare winter severity over the years and link this metric to various activities and maintenance operations. However, this existing index has not fully captured the complexity and regional variability of Michigan's weather conditions. In addition, to incorporate this index for resource allocation and budget management, it is essential to correlate it with winter maintenance costs over the years to establish its merits for this particular application. To address these limitations, this study developed and validated a Modified Weather Severity Index designed explicitly for Michigan. The project aimed to create a more accurate, reliable and actionable proxy for estimating material costs associated with winter maintenance, thereby optimizing operational efficiency and financial planning.

"Implementation of Artificial Intelligence to Improve Winter Maintenance," Exploratory Advanced Research Program Fact Sheet, Federal Highway Administration, December 2021.
https://highways.dot.gov/sites/fhwa.dot.gov/files/FHWA-HRT-21-090.pdf
From the fact sheet: The union of technology and transportation is leading to advancements in how decisions are made and deployed for winter maintenance activities. Federal Highway Administration (FHWA) is investigating the use of artificial intelligence (AI) to collect and analyze data that could dramatically improve winter maintenance operations, safety and mobility, as well as reduce costs and labor hours and enhance pavement design and management. Data-Driven MDSS (Dr. MDSS) looks to AI to provide next-level analysis of real-world situations in real time, addressing the risks and challenges of conducting onsite assessments. Dr. MDSS is a type of MDSS that focuses on the access to and handling of internal and external data to make decisions. FHWA's Exploratory Advanced Research (EAR) Program is supporting research on the potential development of a Dr. MDSS prototype for State departments of transportation (DOTs). Researchers from the Michigan Technological Institute are conducting the

research project, "Autonomous Winter Road Maintenance Decision Making Enabled by Boosting Existing Transportation Data Infrastructure with Deep and Reinforcement Learning."

Related Resource:

"Enhancing Winter Road Maintenance via Cloud Computing," Mohammad Hossein Tavakoli Dastjerdi, Zhen Liu, Behnam Azmoon and Xiaoyong Yuan, *IEEE Internet Computing*, Vol. 27, Issue 4, pages 6-14, April 2023.
Citation at https://ieeexplore.ieee.org/document/10098262
From the abstract: In this article, we develop an AI-enhanced cloud computing framework to enable the autonomous decision-making quality and precision of winter road operations for connected living, namely, the Smart Maintenance Decision Support System (SmartMDSS). With support from the Federal Highway Administration and Michigan Department of Transportation, we are among the first to develop AI-enabled tools for practical winter road maintenance decision making. On the front end, SmartMDSS provides a user-friendly graphical interface showing all of the valuable data and winter operations for specific points on the road and sends necessary warnings and notifications. On the back end, SmartMDSS extracts and analyzes data and makes winter road maintenance decisions. A convolutional neural network has been successfully employed to identify the snow coverage on the road surface. Decision-making algorithms were proposed and implemented to support the road engineers and operators for real-time winter maintenance operations.

3.5 Equipment and Facilities

Research in Progress: Development of a Salt Spreader Controller Program Using Machine-Sensed Roadway Weather Parameters and Climate Data, Massachusetts Department of Transportation, start date: March 2025; expected completion date: December 2027.
Project description at https://trid.trb.org/View/2543223
From the project description: The Massachusetts Department of Transportation (MassDOT) has recently completed a research project on leveraging the instrumented mobile road weather information system (RWIS), computer vision and a new salt application model. The research was aimed at developing four critical aspects of the intelligent salt application system, including hardware (i.e., data collection I/O and power supplies system), software (i.e., data logging, synchronization and data fusion), algorithm (i.e., road surface classification (RSC) algorithm), and model (i.e., the salt rate prediction (SRP) model) so that an optimized salt application decision can be provided to the actuator to treat the road surfaces. Through this study, a complete hardware/software system with automated RSC and SRP algorithms has been developed, pilot-tested and validated with promising performance. The performance of the developed system showed good results. Once implemented in a more extensive fleet of MassDOT's material spreaders utilized during winter operations, it could save a significant amount of salt. The goal of this research is to leverage the prototype system from the previous study and to implement 1) a fully validated spreader controller system that is operated in a fleet of MassDOT's snowplowing trucks and 2) an intelligent salt treatment program that will include weather forecasting information to better prepare for challenging situations, such as freezing rain, black ice, etc.

"Influence of Snowfall on the Fuel Consumption of Winter Maintenance Vehicles," Dinesh Reddy Challa, Matthew J. Eagon and William F. Northrop, *Transportation Research Part D: Transport and Environment*, Vol. 139, February 2025.
Citation at https://www.sciencedirect.com/science/article/abs/pii/S1361920924005005?via%3Dihub
From the abstract: Winter maintenance vehicle fuel consumption increases with snowfall due to changes in road conditions and driving behavior. Quantifying fuel use is important for estimating costs

and for understanding the impact of snow-clearing operations on the environment. Calculating fuel economy is challenging in snowplows because recorded onboard diagnostics (OBD) data often do not include mass, which can fluctuate significantly when applying de-icing substances to the road. This paper outlines a novel method to isolate fuel usage associated with snowfall, accounting for gross vehicle weight, using OBD data. For days with snowfall totaling two inches or more, fuel use rose about 16.5% to 22.9% as compared to days without snowfall. Fully loaded trucks were found to use 13.2% to 18.5% more fuel than half-loaded trucks. The results could be used in practice by motivating better fleet management strategies, for example by optimizing de-icing loads, or to model the feasibility of snowplow electrification.

Snow Plow Performance Measures in Non-RWIS Locations, Gang Jiang, Biao Kuang, Zhenhua Shi, Zhihao Ma and Jianli Chen, Utah Department of Transportation, August 2024.
https://rosap.ntl.bts.gov/view/dot/79412
From the abstract: This project aims to enhance traffic safety by developing an Artificial Intelligence (AI) model and the weather interpolation method to evaluate snow cover conditions on road surfaces using existing roadside Closed- Circuit Television system (CCTV) images in non-Road Weather Information System (RWIS) locations. Snow-cover significantly impacts traffic safety, contributing to 24 percent of annual weather-related vehicle crashes. In Utah, where snow seasons can last up to seven months with over 25 winter storms annually, understanding snow-cover condition in real time is crucial for effective snow plow management by the Utah Department of Transportation (UDOT) and for public safety. Traditional methods for assessing road conditions rely on RWIS, which has limited coverage. The project will utilize image data from CCTV cameras to train a deep learning-based AI model for automatic evaluation of snow-cover condition. The methodology includes processing images to create labeled datasets, developing AI models based on AlexNet as the deep learning algorithms, and implementing these models to analyze real-time snow-cover conditions. Additionally, a weather interpolation method is developed to estimate real-time weather status in non-RWIS areas. The validation results show that our developed AI model can achieve over 97 percent accuracy in identifying various snow-cover states, including clear, partial snow, and full snow conditions. Furthermore, the developed weather interpolation method can provide a detailed view of the spatial distribution of air temperature, relative humidity, wind speed, precipitation, and snow accumulation. By leveraging existing CCTV networks, this project offers a cost-effective solution for large-scale, real-time road condition monitoring, closing information gaps, and enhancing winter road safety management.

Deployment of a Snowplow Driver-Assist System, Brian Davis, Katelyn Schwieters, Nichole L. Morris and Max Donath, Minnesota Department of Transportation, June 2023.
https://mdl.mndot.gov/items/202327
From the abstract: Snowplow operators are often tasked with clearing snow from roadways under challenging conditions. One such situation is low visibility due to falling or blowing snow that makes it difficult to navigate, stay centered in the lane and identify upcoming hazards. To support snowplow operators working in these conditions, University of Minnesota researchers developed a snowplow driver-assist system that provides the operator with visual and auditory information that is suitable for low-visibility situations. A lane-guidance system uses high-accuracy Global Navigation Satellite System (GNSS) and maps of the roadway to provide information to drivers about their lateral positions. A forward-obstacle-detection system uses forward-facing radar to detect potential hazards in the roadway. The design of the system, and in particular its interface, is guided by extensive user testing to ensure the system is easy to understand, easy to use and well liked among its users.

The system was deployed in two phases over the 2020-2021 and 2021-2022 winter seasons. In total, nine systems were deployed on snowplows across Minnesota, four in the first winter season and an

additional five in the second. Participating truck stations represented all eight MnDOT districts as well as Dakota County. Over the course of the deployment, additional user feedback was collected to identify system strengths and areas for improvement. The system was found to be a cost-effective addition to snowplows that increase driver safety, reduce plow downtime and increase driver efficacy for plowing operations, thus providing support to operators working in demanding, low-visibility conditions.

Reducing Winter Maintenance Equipment Fuel Consumption Using Advanced Vehicle Data Analytics, William Northrop, Dinesh Reddy Challa, Matthew Eagon and Peter Wringa, Minnesota Department of Transportation, January 2023.
https://mdl.mndot.gov/items/202303
From the abstract: This project analyzes the impact that idling and snowfall have on the fuel consumed by MnDOT's snowplow fleet, with the underlying objective to determine and advise MnDOT on ways to reduce fuel usage of the fleet using vehicle telematics data. This is a significant problem to solve as fuel use reduction contributes to MnDOT's sustainability goals of achieving a 30% reduction in fossil fuel use and greenhouse gas (GHG) emissions from 2005 levels by 2025. Furthermore, rising fuel costs are a future cause for concern due to an increase in business operational costs that increases the burden on taxpayers to keep roads safe in winter. This problem is challenging because existing on-board diagnostics (OBD) data do not contain mass information for the trucks' fuel use, which can fluctuate significantly when they are applying deicing substances to the road. Taking a mean value for the vehicle mass, we observe a clear positive correlation between snowfall and average fuel use. For days with snowfall totaling 4 inches or more, fuel use rises more than 25% on average compared to days without snowfall. In addition, the results from the idling analysis indicate that the idling time associated with the fleet is about 23% of total recorded hours and constitutes about 4.3% of the total fuel used. Daily idling activity reports containing information about idling events and fuel economy are generated for the sampled vehicles and shared with MnDOT.

3.6 Materials

District Highway Maintenance Research On-Call (ROC) 2023-09 – Task 2: Evaluation of New Technologies for Tracking the Distribution of Deicing Materials, Erin Lammers-Staats, Zane Raudenbush, Munir D. Nazzal and Benjamin Blandford, Ohio Department of Transportation, May 2023.
https://rosap.ntl.bts.gov/view/dot/73199/dot_73199_DS1.pdf
From the abstract: This report summarizes the results of a research task that was conducted to analyze Ohio DOT's use of liquid deicing materials and the tracking capabilities of its snowplows' distribution systems. The objective of the task was to identify areas for improvement in terms of tracking the liquid application rates and provide ideas on how to evaluate new technologies that may improve tracking. To achieve this objective, a comprehensive audit of Ohio's current state of the practice was conducted. Areas for improvement were identified and constraints were noted. In addition, a nationwide survey was distributed; the survey served as a metric to compare Ohio's state of the practice as well as providing leads for new technologies to investigate. Then, vendors were solicited for information about liquid tracking systems that could fit into Ohio's infrastructure and offer the enhancements Ohio was seeking. Brief research was done on each of these new technologies. Lastly, an evaluation matrix was developed so ODOT [Ohio DOT] can continue pursuing these options. The evaluation matrix lists criteria that should be examined as well as specific elements within each criteria. It also proposes ideas on how to practically evaluate or measure each criteria element. ODOT can use the information presented in this report to select new liquid tracking technologies to test within their research program, and continue working towards optimizing their response to winter weather.

Effect of Warmer Minnesota Winters on Freeze-Thaw Cycles, Masrur Mahedi, Daniel Rajewski, Sunghwan Kim, Halil Ceylan, In-Ho Cho and Eugene S. Takle, Minnesota Department of Transportation, July 2022.
https://mdl.mndot.gov/items/202204
From the abstract: An increase in freeze-thaw events will result in detrimental impacts on pavement systems. However, the impacts of recent climate changes on freeze-thaw cycles have not been well studied, although they are of interest to a broad number of transportation agencies. In this study, the number of freeze-thaw events at typical air temperature sensor level (e.g., 6 feet above the earth's surface) as well as at different pavement layers and critical sub-pavement locations such as saturated subgrade within the active zone were quantified. In response to global warming, current work resulted in rigorously quantified freeze-thaw events rooted in climate data from 1941 to 2020. Results indicated that in the recent 40 years (i.e., 1981-2020), Minnesota winters have become warmer by 1-2 °F daytime and 2-5 °F nighttime temperatures. With a decrease in freezing temperatures, the yearly number of freeze-thaw cycles tended to decrease at shallow pavement depths (< 6 inches), whereas remained sporadic at deeper pavement layers. The decreases in freeze-thaw events at shallower depths were significant during the early and late winter months. However, the annual freeze-thaw events at the air temperature sensor level were randomly distributed throughout the analysis period.

3.7 Training

Research in Progress: Enhancing Current Snow and Ice Training Practices by Incorporating the Use of a Customized Snow and Ice Simulator, Ohio Department of Transportation, start date: August 2022; expected completion date: August 2024. (**Note**: This project appears on the Ohio DOT website as an active research project.)
Project description at https://trid.trb.org/View/1994580
From the project description: Winter maintenance operations are the Ohio Department of Transportation's (ODOT) premier service. ODOT strives to set a standard of excellence through comprehensive planning that includes equipment readiness, truck routing, material inventory control and training. Over the past few years, staffing at government agencies has been decreasing. As this trend continues ODOT is experiencing a loss of seasoned full-time drivers who have made the "snow warriors" of the past. Much of the replacement are auxiliary and seasonal drivers with little training. The intent of this project is to develop customized simulation that can mimic truck operations, actual Ohio roads, and influences from snow and ice on both the truck and the plow. This will allow drivers to hone their skills before taking a plow onto a busy Ohio highway/interstate during a snow event. This research is needed to complete the development of a customized simulator training program.

Related Resource:

> **Evaluate Opportunities to Provide Training Simulation for ODOT Snow and Ice Drivers – Phase 2**, John E. Ash, Jiaqi Ma, Mehdi Norouzi, Ming Tang and Xuefu Zhou, Ohio Department of Transportation, February 2022.
> https://rosap.ntl.bts.gov/view/dot/73242
> *From the abstract:* Recently, the Ohio Department of Transportation (ODOT) noted a desire to enhance the current training offered to snowplow drivers by integrating driving simulation into the overall curriculum. As such, ODOT purchased a snowplow driving simulator to use for this purpose. In this project, the research team helped ODOT set up the simulator, developed and implemented custom training environments and scenarios, and developed training materials to be used in snow and ice driver education training programs by both drivers and instructors. Virtual environments were modeled directly after actual ODOT facilities in order to allow drivers to gain familiarity with the details of their future work environment. Training scenarios were created to allow for teaching

and evaluation of specific skills under varying environments in the simulator (e.g., how to plow an intersection). It is the hope of this project that the use of the simulator and developed materials can help ODOT drivers gain more experience before going out onto the road, thus improving their efficiency, as well as safety for both themselves and the motoring public.

Synthesis Study on Employing Snowplow Driving Simulators in Training, Luciana Debs, Yanchao Zheng, Jesutoba Ademiloye, Yunfeng Chen and Jiansong Zhang, Indiana Department of Transportation, January 2023.
https://docs.lib.purdue.edu/cgi/viewcontent.cgi?params=/context/jtrp/article/3373/&path_info=SPR_4651_to_upload.pdf
From the abstract: Departments of Transportation (DOTs) need to mobilize workers under harsh weather conditions for winter operations. Traditional snowplow driver training at INDOT [Indiana DOT] is usually conducted annually before the snow season; therefore, it does not replicate the conditions which drivers will be exposed to during winter operations. To this point, some state DOTs have incorporated simulators in their snowplow driver training. Despite this raised interest, few studies have (1) surveyed other state DOTs about the use of this equipment in winter operations driver training, or (2) provided a systematic consideration of all factors involved in the decision to use driving simulators in snowplow driver training. To fill these gaps, the present study synthesizes information from previous literature, revises current information from INDOT, and surveys other state DOTs to identify the benefits and challenges of driving simulators for snowplow driver training. A mixed methods approach was utilized including a review of current INDOT practices, interviews with stakeholders, a survey of other state DOTs, and results from a pilot training. Based on the findings, the researchers recommend that INDOT continues to explore the use of driving simulators for training purposes in addition to the yearly snowplow driver training, due the ability to reinforce learning in a safe environment. Moreover, the research team suggests the following areas for further research: evaluating optimal simulator "seat time," peer learning in simulator training, and the impact of experience level and work assignment in the perception of driving simulator training effectiveness.

3.8 Technology

Research in Progress: Obtaining Reliable Pavement Friction Measurements Using Connected Vehicles, New England University Transportation Center, start date: January 1, 2026; expected completion date: December 31, 2026.
Project description at https://www.umass.edu/neutc/projects/obtaining-reliable-pavement-friction-measurements-using-connected-vehicles
From the project description: Pavement friction is a critical factor influencing vehicle control and stopping distance, particularly under wet conditions, yet current measurement practices rely on infrequent and labor-intensive testing methods. These limitations prevent agencies from identifying hazardous low-friction locations in a timely manner. This project investigates whether connected vehicle sensor data can provide a reliable and continuous alternative for pavement friction monitoring.

The research will validate friction estimates derived from connected passenger vehicles against locked-wheel skid testing and invasive and non-invasive roadway sensors. Data will be collected on multiple pavement types along a test corridor in Massachusetts and analyzed using statistical and machine learning methods to relate vehicle-based friction values to standard skid numbers. The project will develop conversion models and data-integration techniques to enable agencies to incorporate connected vehicle friction data into pavement and safety management systems, supporting proactive maintenance and improved roadway safety.

"Iowa DOT's Visibility Technology Helps Snowplow Operators 'See' Roads During Severe Weather," *Transportation Matters*, Iowa Department of Transportation, January 13, 2026.
https://iowadot.gov/transportation-matters/2026-01-13/iowa-dots-visibility-technology-helps-snowplow-operators-see-roads-during-severe-weather
From the blog post: We can't stop Mother Nature, but technology offers a solution to increase the safety for staff and the motoring public through a snowplow guidance system that provides more precise by-the-inch vehicle positioning within a pre-mapped lane. Originally engineered for tractors and motor graders, John Deere Path is a road mapping guidance system designed to help operators with real-time visualization and navigation of road boundaries, especially in challenging low-visibility conditions. By applying Deere's agricultural satellite technology to DOT snowplows, operators can "see" their position relative to the road to enhance safety and operational efficiency.

"Exploring the Correlation Between Winter Severity Indices and Winter Maintenance Costs: Insights and Comparative Analysis from Nationwide Practices," Ardeshir Fadaei, Farish Jazlan, Amiralin Soltanpour, Hamid Mozafari, Ali Zockaie, Mehrnaz Ghamami and James Roath, *Transportation Research Record,* OnlineFirst, November 2025.
Citation at https://journals.sagepub.com/doi/abs/10.1177/03611981251393246
From the abstract: Winter maintenance operations are essential for safe and efficient transportation, yet unpredictable weather introduces major challenges in cost and material planning. A single severe snowfall can deplete resources midway through the season, while milder-than-expected winters may result in unused surpluses. The Winter Severity Index (WSI) provides a standardized measure of winter intensity, offering a promising tool to address these challenges. This study explores the relationship between WSIs and winter maintenance costs through a nationwide survey of state DOTs and Clear Roads survey data. The Clear Roads survey analysis involves regression models, assessing the relationship between the Accumulated Winter Season Severity Index (AWSSI) and winter maintenance expenditures across different U.S. climate divisions. AWSSI was used not as a recommended tool for operations, but as a nationally available and consistent index to investigate whether winter severity is statistically associated with cost trends on a broad scale. The study also assessed nonlinear regression models, which yielded similar results to linear models; the linear model was, therefore, retained for its simplicity and interpretability. Results show significant correlation within various climate clusters, indicating that weather severity can explain cost variability. The study reveals that WSIs can improve winter maintenance budget management, but their effectiveness is regionally nuanced. Customized WSIs are essential to improve resource planning, as the findings indicate that AWSSI does not work optimally in all geographic contexts. The study also identified best practices by state departments of transportation (DOTs), such as integrating WSIs with real-time tools such as the Road Weather Information Service and the Maintenance Decision Support System, to enhance planning accuracy and responsiveness.

"Smart Snow Removal: How AI is Transforming Urban Winter Management," Timothy Menard, *Smart Cities Dive*, January 27, 2025. (Originally published in *American City and County.)*
https://www.smartcitiesdive.com/news/archive-acc-smart-snow-removal-how-ai-is-transforming-urban-winter-management/754774/
From the article: As winter's icy grip tightens on cities across North America, urban planners and transportation officials are turning to innovative solutions to combat the age-old challenge of snow removal.

Among these cutting-edge approaches, snowplow signal prioritization technology promises to modernize how cities manage their winter maintenance operations. This advanced system allows

snowplows to navigate through intersections more efficiently, ensuring rapid snow clearance and safer travel for community members.

Evaluating the Robustness of MDSS Forecast and Compliance with Recommendations, Gregory L. Brinster, Jairaj Desai, Myles W. Overall, Christopher Gartner, Rahul Suryakant Sakhare, Jijo K. Mathew, Nick Evans and Darcy M. Bullock, Indiana Department of Transportation, September 2024.
https://rosap.ntl.bts.gov/view/dot/81833
From the abstract: The Indiana Department of Transportation (INDOT) adopted the Maintenance Decision Support System (MDSS) for user defined plowing segments in the winter of 2008–2009. Since then, many new data sources, including connected vehicle data, enhanced weather data and fleet telematics have been integrated into INDOT winter operations activities. The objective of this study was to use these new data sources to conduct a systematic evaluation of the robustness of the MDSS forecasts. During the 2023–2024 winter season, 26 unique MDSS forecast data attributes were collected at 0-, 1-, 3-, 6-, 12-, and 23-hour intervals from the observed storm time for 6 roadway segments during 13 individual storms. In total, over 888,000 MDSS data points were archived for this evaluation. This study developed novel visualizations to compare MDSS forecasts to multiple other independent data sources, including connected vehicle data, National Oceanic and Atmospheric Administration (NOAA) weather data, road friction data and snowplow telematics.

Three Indiana storms, with varying characteristics and severity, were analyzed in detailed case studies. Those storms occurred on January 6th, 2024, January 13th, 2024 and February 16th, 2024. Incorporating these visualizations into winter weather after action reports increased the robustness of post-storm performance analysis and allowed road weather stakeholders to better understand the capabilities of MDSS. The results of this analysis will provide a framework for future MDSS evaluations and implementations and training tools for winter operation stakeholders in Indiana and beyond.

NCHRP Research Report 1075: Becoming a Tech-Savvy DOT of Tomorrow: A Playbook for States, J. Kaliski, S. Hecke, N. Higgins, L. Pickett, G. Leao, A. Patel and B. Bream, 2023.
https://www.nationalacademies.org/publications/27293
From the foreword: The research identifies specific issues, effects and opportunities for agency response, management, and adaptation to disruptions and disruptors. Building on interviews and workshops as well as an extensive review of literature and agency documents, the Playbook defines disruption in a transportation agency context and leads readers through a process of self-assessment, including strategic approaches for addressing agency-specific challenges with implementing disruptive technologies. These include developing new public–private partnerships, determining the role of the agency in strategic management of new disruptions (or potential new disruptions), and addressing the role of customer service within this context.

The Playbook describes the following six steps:

- Become technology aware.
- Define a technology-aware vision.
- Identify new disruptive technologies and potential impacts on DOT objectives.
- Adapt an organizational performance management process to incorporate disruptive technologies.
- Select practical performance management strategies for the near and long terms.
- Implement and manage continuous change.

Related Resource:

NCHRP Web-Only Document 371: Impact of New Disruptive Technologies on the Performance of DOTs, John Kaliski, Sam Van Hecke, Nathan Higgins, Leah Pickett, Guilherme Leao, Alpesh Patel, Baird Bream, Steve Lockwood and Deb Miller, 2023.
Publication available at https://www.nationalacademies.org/publications/27292
From the description: NCHRP Web-Only Document 371: Impact of New Disruptive Technologies on the Performance of DOTs, from TRB's National Cooperative Highway Research Program, is supplemental to NCHRP Research Report 1075: Becoming a Tech-Savvy DOT of Tomorrow and develops a guide for state DOTs and other transportation planning agencies to understand, predict, plan for, and adapt to the potential impacts of emerging disruptive technologies.

"Winter Road Surface Condition Recognition Using Semantic Segmentation and the Generative Adversarial Network: A Case Study of Iowa, U.S.A.," Mingjian Wu, Tae J. Kwon and Nancy Huynh, *Transportation Research Record 2678*, Issue 5, pages 1-12, July 2023.
https://www.researchgate.net/publication/372664815_Winter_Road_Surface_Condition_Recognition_Using_Semantic_Segmentation_and_the_Generative_Adversarial_Network_A_Case_Study_of_Iowa_USA
From the abstract: Adverse road surface conditions (RSCs) are a significant concern for traffic safety and mobility during the winter season. Dealing with this issue requires the prompt execution of maintenance operations to restore safe driving conditions. The faster maintenance personnel are made aware of the dangerous conditions, the faster they can mobilize to mitigate adverse RSCs. Therefore, the speed at which RSC information is provided is vital for reducing potential road-related incidents and maintaining mobility. Intending to improve the delivery of RSC information, this study proposes developing a deep learning-based method through the usage of road weather information system (RWIS) images to automate the RSC classification process. While the RWIS collects images that give a direct view of the road, the traditional manual way of utilizing these images for RSC monitoring is laborious and time-consuming. To overcome this challenge as well as other limitations associated with previously developed RSC recognition methods, the application of deep neural networks using imagery data is investigated here. More specifically, the application of semantic segmentation (SS) and generative adversarial network (GAN) techniques in automating RSC recognition was adopted in an attempt to predict the locations of drivable areas and indicate the snow hazard level solely based on RWIS images. Case study results from Iowa, U.S.A., show that both SS and GAN techniques perform their tasks with a high degree of accuracy.

"Developing a Cost-Effective Mobile-Based System for Collecting On-Demand Road Condition Images for Snowplow Operations Management," Pooya Darghiasi, Anil Baral and Mohsen Shahandashti, *International Conference on Transportation and Development 2023*, June 2023.
Citation at https://ascelibrary.org/doi/10.1061/9780784484883.012
From the abstract: Mobile devices (e.g., tablets and smartphones) have become increasingly popular for collecting and processing transportation data for various purposes without the need for complicated systems that require operator training. In recent years, several state departments of transportation (state DOTs) have equipped snowplow fleets with different systems to communicate road condition images to assist winter operations supervisors in making operational decisions during winter storms. The existing systems usually consist of several pieces of equipment and automatically transmit the road condition images at only predetermined intervals. They are expensive because they require multiple pieces of equipment installed in the snowplows. Furthermore, existing systems do not enable supervisors in the office to request images if the received images are insufficient to determine the conditions of the roads. This study proposes a cost-effective and easy-to-use mobile-based system for operators to collect on-demand road condition images from fields or offices using the capabilities of

mobile devices. The proposed data collection system was implemented in the TxDOT Wichita Falls District for the 2021–2022 winter season. The collected images were visualized in an ArcGIS map-based interface and assisted winter operations supervisors in asset management and operational decisions during winter storms. The results revealed that even operators with little experience operating technological devices could still operate the system using mobile devices. Moreover, these devices could be easily removed from the fixed mounts in snowplows to capture images that were not directly in front of the snowplows. The developed system also facilitated requesting road condition images by supervisors in offices using a web-based add-on when the received images are insufficient to determine the state of the roads. The proposed system simplifies the on-demand data collection process for operators and eliminates the need to conduct extensive training for operators.

Completed Research, Aurora Pooled Fund Study, undated.
https://www.aurora-program.org/research/completed
As its website notes, "The mission of Aurora and its members is to seek to implement advanced road weather information systems (RWIS) that fully integrate state-of-the-art roadway and weather forecasting technologies with coordinated, multi-agency weather monitoring infrastructures." Listed below are links to research studies completed in 2024, 2025 and 2026:

- Standardized Framework for Winter Weather Road Condition Indices
- An Intelligent Human-Centric Communication System for Adverse Weather and Road Conditions
- Automating Variable Speed Limits Using Weather, Traffic and Friction Data
- Optimal RWIS Sensor Density and Location – Phase 4
- Road Weather Management Using Connected Vehicle Technology
- Assessment of Connected Vehicle Friction Measurement Data on DOT Winter Maintenance Use Cases
- Integration of Connected Vehicle and RWIS Technologies
- Roadway Ice/Snow Detection Using a Novel Infrared Thermography Technology
- Evaluation of Spring Load Restriction Removal Protocols

3.9 Safety and Outreach

Research in Progress: Quantitative Assessment of Anti-Icing Efficacy on Highway Surfaces Using Light Reflectance, Center for Transformative Infrastructure Preservation and Sustainability, start date: October 2025; expected completion date: October 2027.
Project description at https://www.ctips.org/projects/downloads/2025-ctips-053-utc-sheet.pdf
From the project description: The project aims to quantify road surface condition under adverse weather in North Dakota. First, the current winter maintenance and winter road condition monitoring practices across North Dakota will be reviewed. Historical crash data will be used to identify high-risk roadway segments encountering elevated crash frequencies and/or severities related to adverse road surface conditions. The project aims to quantify the safety performance to estimate and predict crash occurrences related to adverse weather conditions using statistical modeling techniques and network screening analysis. Once the importance of road surface condition on safety is quantif[ied], type of surface condition (ice, snow, slush) on highways using diffuse reflectance spectroscopy (DRS) will be identified. A physical model for near-infrared reflectance of road surface will be developed to classify the surface condition in a noncontact manner. The models will be developed under controlled conditions and will be evaluated under field condition by determination of the optical properties of water, snow and ice (and black ice). In the next objective, DRS based discriminative to measure brine eutectic point and efficacy will be developed by generating samples with different portions of water, salt

and beet juice (primarily used in North Dakota) under different temperature. Through noncontact quantification of deicer efficacy, the project contributes to preservation of transportation infrastructure and safety. The research team will develop deterministic and data-driven models to correlate DRS features under different brine conditions with respect to eutectic points in a controlled environment, and benchmarking and compare the results of DRS brine models with observations. The final task of this objective is to develop a low-cost in-situ optical sensor framework for field deployment using diode lasers, super luminescent LEDs, hyperspectral camera, single-pixel and array photodiodes, and spectral filters. The payload SWaP (size, weight and power) analysis for potential Unmanned Aerial Systems (UAS) applications. The research team will establish an UAS operation training program for students to get UAS licensed, to shadow UAS-assisted inspections, to analyze UAS data.

"Identifying Snowplow Truck Crash Hotspots and Spatial Analysis of Crashes in the Mountainous Roadways," Imran Reza, Muhammad Tahmidul Haq and Khaled Ksaibati, *International Journal of Crashworthiness*, Vol. 30, Issue 1, pages 23-35, 2025.
Citation at https://doi.org/10.1080/13588265.2024.2366437
From the abstract: Analysis of spatial patterns can provide an efficient answer to the problem of locating global or local patterns of the spatial distribution of traffic crashes. Approximately 21% of vehicle crashes in the United States occur due to inclement weather, costing the U.S. economy more than $217.5 billion yearly. One major road winter maintenance activity is snowplow and spreading salt on the road surface to improve the driving condition. The potential for rear-end collisions or conflicts between motorists and Snowplow Trucks (SPTs) is a major safety concern. This study extensively applies Ripley's K-function, the global Moran's I measure and the Getis–Ord Gi* function along with Kernel Density Estimation and Network-based Kernel Density Estimations with the aim of analysing snowplow-involved crash hotspots in the state of Wyoming. The positive Moran's I, the high z-scores and the small *p* values indicate that Snowplow truck crashes were spatially clustered.

"Assessing the Safety Impacts of Winter Road Maintenance Operations Using Connected Vehicle Data," Minsoo Oh and Jing Dong-O'Brien, *Accident Analysis and Prevention*, Vol. 209, January 2025.
Citation at https://www.sciencedirect.com/science/article/abs/pii/S0001457524003828?via%3Dihub
From the abstract: This paper investigates the impacts of winter maintenance operations (WMO) on road safety under different weather conditions using connected vehicle data. In particular, the impacts of WMO on incident-induced delays (IID) and harsh braking events are highlighted, representing the influence on traffic flow and vehicle stability, respectively. Taking advantage of emerging connected vehicle data, the impacts of WMO on IIDs and vehicle harsh braking events are estimated. Data analysis revealed that WMO plays an important role in reducing the mean IID and the average number of harsh braking events, particularly when roads were covered with ice, frost, slush, or snow in snowy weather. The presence of WMO reduced the mean IID from 145.93 veh-h to 57.70 veh-h, representing a 60% decrease, and the number of harsh braking events from 3.58 cases per crash to 2.90 cases per crash, making a 19% reduction. Last, the multiple linear regression (MLR) model highlights that WMO effectively reduces IID by 23.36 veh-h. In addition, the MLR model indicates that IID is influenced by traffic volume, driving behaviors immediately before a crash, crash severity, road weather conditions, with more severe crashes and worse pavement conditions contributing to longer delays. These findings suggest that the WMO can improve road safety by reducing incident-induced delays and improving traffic stability in winter weather conditions.

"Simulating Future Climate Change Impacts on Snow- and Ice-Related Driving Hazards in Arctic-Boreal Regions," Heather E. Greaves, Natalie T. Boelman, Todd J. Brinkman, Glen E. Liston, Laura R. Prugh and Adele K. Reinking, *Environmental Research Letters*, Vol. 18, No. 2, February 2023. https://iopscience.iop.org/article/10.1088/1748-9326/acb5b1

From the abstract: As Arctic and boreal regions rapidly warm, the frequency and seasonal timing of hazardous driving conditions on all-season Arctic-boreal roads are likely to change. Because these roads link remote Arctic areas to the rest of the North American road system, climate change may substantially affect safety and quality of life for northern residents and commercial enterprises. To gain insight into future hazardous driving conditions, we built Random Forest models that predict the occurrence of hazardous driving conditions by linking snow, ice, and weather simulated by a spatially explicit modeling system (SnowModel) to archived road condition reports from two highly trafficked all-season northern roads: the Dalton Highway (Alaska, USA) and Dempster Highway (Yukon, Canada). We applied these models to downscaled future climate trajectories for the study period of 2006–2100. We estimated future trends in the frequency and timing of icy, wet-icy, and snowy road surfaces, blowing and drifting snow, and high winds. We found that as the climate warms, and the portion of the year when snow and ice occur becomes shorter, overall frequency of snow storms and ice- and snow-related driving hazards decreased. For example, the mean number of days per year when roads are covered in snow or ice decreased by 51 d (−21%) on the Dalton Highway between the 2006–2020 and 2081–2100 time periods. However, the intensity of storms was predicted to increase, resulting in higher mean annual storm wind speeds (Dalton +0.56 m s−1 [+17%]) and snowfall totals (Dalton +0.3 cm [+36%]). Our models also predicted increasing frequency of wet-icy driving conditions during November, December, January, and February, when daylength is short and hazardous conditions may be more difficult to perceive. Our findings may help road managers and drivers adapt their expectations and behaviors to minimize accident risk on Arctic-boreal roads in the future.

Appendix A: Survey

The survey below was provided in an online format to Clear Roads members and representatives of Norwegian Public Roads Administration.

Describing New Practices

In this survey, a *new practice* refers to any innovative procedure, policy, tool, equipment or material that your agency is interested in trying, or has tested, implemented or determined is not an appropriate fit for your agency within the last five years.

You'll have an opportunity to describe new practices in six topic areas:

- Planning
- Equipment and facilities
- Materials
- Training
- Technology
- Safety and outreach

New Practice: Planning

(Required) Has your agency tested or implemented any new practices related to **planning**? New planning practices may include, but are not limited to:

- Cost analysis
- Focus on Complete Streets program
- Performance metrics
- Preparing for and responding to extreme weather
- Resource management
- Severity maps and indices
- Snowplow route optimization

- Yes (Directed the respondent to **Question 1** below and the remaining questions in the survey, if applicable**.**)
- No (Directed the respondent to **New Practice: Equipment and Facilities** and the remaining questions in the survey, if applicable**.**)

1. Please briefly describe the new planning practice your agency recently tested or implemented, using the topic areas below.
    - Practice description:
    - Idea origin:
    - Pilot effort:
    - Expected benefits:
    - Challenges or barriers:
    - Outcomes:
    - Other comments:
2. How long do you expect it will take for the new practice to become standard operating procedure?
3. Can this new practice be adapted for use by other agencies?
    - No
    - Yes (Please describe how another agency might adapt the new practice.)

4. Please provide links to any documents related to your agency's new planning practice. Send any files not available online to susan.johnson@ctcandassociates.com.
5. Are there other new practices in the **Planning** topic area you'd like to share?
    - No
    - Yes (Please identify other new planning practices your agency is interested in or implementing.)

New Practice: Equipment and Facilities

(Required) Has your agency tested or implemented any new practices related to **equipment and facilities**? New equipment and facilities practices may include, but are not limited to:

- Advanced material spreader controls
- Brine makers
- Building design and location strategies
- Efficient equipment configurations (modern wings, segmented cutting edges)
- Plow blades
- Plow trucks

- Yes (Directed the respondent to **Question 1** below and the remaining questions in the survey, if applicable**.**)
- No (Directed the respondent to **New Practice: Materials** and the remaining questions in the survey, if applicable**.**)

1. Please briefly describe the new practice related to equipment and facilities that your agency recently tested or implemented, using the topic areas below.
    - Practice description:
    - Idea origin:
    - Pilot effort:
    - Expected benefits:
    - Challenges or barriers:
    - Outcomes:
    - Other comments:
2. How long do you expect it will take for the new practice to become standard operating procedure?
3. Can this new practice be adapted for use by other agencies?
    - No
    - Yes (Please describe how another agency might adapt the new practice.)
4. Please provide links to any documents related to your agency's new equipment and facilities practice. Send any files not available online to susan.johnson@ctcandassociates.com.
5. Are there other new practices in the **Equipment and Facilities** topic area you'd like to share?
    - No
    - Yes (Please identify other new equipment and facilities practices your agency is interested in or implementing.)

New Practice: Materials

(Required) Has your agency tested or implemented any new practices related to **materials**? New materials practices may include, but are not limited to:

- Additives
- Anti-icers

- Deicers (types and methodologies)
- Liquid materials
- Material application
- Material selection to address environmental concerns
- Material testing
- Prewetting
- Salt management

- Yes (Directed the respondent to **Question 1** below and the remaining questions in the survey, if applicable**.**)
- No (Directed the respondent to **New Practice: Training** and the remaining questions in the survey, if applicable**.**)

1. Please briefly describe the new materials practice your agency recently tested or implemented, using the topic areas below.
    - Practice description:
    - Idea origin:
    - Pilot effort:
    - Expected benefits:
    - Challenges or barriers:
    - Outcomes:
    - Other comments:
2. How long do you expect it will take for the new practice to become standard operating procedure?
3. Can this new practice be adapted for use by other agencies?
    - No
    - Yes (Please describe how another agency might adapt the new practice.)
4. Please provide links to any documents related to your agency's new materials practice. Send any files not available online to susan.johnson@ctcandassociates.com.
5. Are there other new practices in the **Materials** topic area you'd like to share?
    - No
    - Yes (Please identify other new materials practices your agency is interested in or implementing.)

New Practice: Training

(Required) Has your agency tested or implemented any new practices related to **training**? New training practices may include, but are not limited to:

- Equipment training
- In-person training
- New driver preparation
- Refresher training
- Simulator training

- Yes (Directed the respondent to **Question 1** below and the remaining questions in the survey, if applicable**.**)
- No (Directed the respondent to **New Practice: Technology** and the remaining questions in the survey, if applicable**.**)

1. Please briefly describe the new training practice your agency recently tested or implemented, using the topic areas below.

- Practice description:
- Idea origin:
- Pilot effort:
- Expected benefits:
- Challenges or barriers:
- Outcomes:
- Other comments:

2. How long do you expect it will take for the new practice to become standard operating procedure?
3. Can this new practice be adapted for use by other agencies?
    - No
    - Yes (Please describe how another agency might adapt the new practice.)
4. Please provide links to any documents related to your agency's new training practice. Send any files not available online to susan.johnson@ctcandassociates.com.
5. Are there other new practices in the **Training** topic area you'd like to share?
    - No
    - Yes (Please identify other new training practices your agency is interested in or implementing.)

New Practice: Technology

(Required) Has your agency tested or implemented any new practices related to **technology**? New technology practices may include, but are not limited to:

- Adaptive (feedback-based) spreader controls
- Artificial intelligence
- Connected vehicle technologies (ABS, windshield wiper deployment)
- GPS/automatic vehicle location (AVL)
- Maintenance decision support system (MDSS)
- Plug-and-play initiative
- Road weather information system (RWIS)

- Yes (Directed the respondent to **Question 1 below** and the remaining questions in the survey, if applicable**.**)
- No (Directed the respondent to **New Practice: Safety and Outreach** and the remaining questions in the survey, if applicable**.**)

1. Please briefly describe the new technology practice your agency recently tested or implemented, using the topic areas below.
    - Practice description:
    - Idea origin:
    - Pilot effort:
    - Expected benefits:
    - Challenges or barriers:
    - Outcomes:
    - Other comments:
2. How long do you expect it will take for the new practice to become standard operating procedure?
3. Can this new practice be adapted for use by other agencies?
    - No
    - Yes (Please describe how another agency might adapt the new practice.)

4. Please provide links to any documents related to your agency's new technology practice. Send any files not available online to susan.johnson@ctcandassociates.com.
5. Are there other new practices in the **Technology** topic area you'd like to share?
    - No
    - Yes (Please identify other new technology practices your agency is interested in or implementing.)

New Practice: Safety and Outreach

(Required) Has your agency tested or implemented any new practices related to **safety and outreach**? New safety and outreach practices may include, but are not limited to:

- Cameras used to assess road condition
- Crowdsourced observations and incident reports
- Educational campaigns
- Roadside messaging/variable speed limits
- Traveler information (511, informational websites)
- Work zone safety

- Yes (Directed the respondent to **Question 1** below and the remaining questions in the survey, if applicable**.**)
- No (Directed the respondent to **Emerging Technologies and Practices** and the remaining questions in the survey**.**)

1. Please briefly describe the new safety and outreach practice your agency recently tested or implemented, using the topic areas below.
    - Practice description:
    - Idea origin:
    - Pilot effort:
    - Expected benefits:
    - Challenges or barriers:
    - Outcomes:
    - Other comments:
2. How long do you expect it will take for the new practice to become standard operating procedure?
3. Can this new practice be adapted for use by other agencies?
    - No
    - Yes (Please describe how another agency might adapt the new practice.)
4. Please provide links to any documents related to your agency's new safety and outreach practice. Send any files not available online to susan.johnson@ctcandassociates.com.
5. Are there other new practices in the **Safety and Outreach** topic area you'd like to share?
    - No
    - Yes (Please identify other new safety and outreach practices your agency is interested in or implementing.)

Emerging Technologies and Practices

In this section, *emerging technologies and practices* refers to those that are not currently market-ready but expected to be publicly available within the next five years.

1. Please briefly describe the emerging technologies or practices that your agency is interested in exploring in each of the topic areas below.

   Planning:
   Equipment and facilities:
   Materials:
   Training:
   Technology:
   Safety and outreach:

2. Please briefly describe any barriers your agency faces in exploring or testing these emerging technologies and practices.

Future Challenges and Assessment

1. Please briefly describe the top five challenges your winter maintenance program currently faces or you foresee facing in next five years.

   Challenge 1:
   Challenge 2:
   Challenge 3:
   Challenge 4:
   Challenge 5:

2. Do you expect your agency can provide the support needed to test or implement new practices to meet these challenges in your winter maintenance program?

   - No
   - Yes (Please describe how you anticipate your agency will support these efforts.)

3. What are the best practices or lessons learned your agency has identified after implementing one or more new practices?

   Best Practice or Lesson 1:
   Best Practice or Lesson 2:
   Best Practice or Lesson 3:

4. What are your top three recommendations for agencies seeking out new practices to implement?

   Recommendation 1:
   Recommendation 2:
   Recommendation 3:

5. Please use this space to provide any comments or additional information about your previous responses.

research for winter highway maintenance

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