Update on Status of AVL/GPS for Winter Operations

Synthesis Report

CLEAR ROADS

research for winter highway maintenance

CTC & Associates LLC

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16. Abstract

Automatic vehicle location (AVL) and Global Positioning System (GPS) technologies are used by state departments of transportation (DOTs) for tracking vehicle location, engine maintenance needs and other uses. While previous Clear Roads Research Program research has explored the range of AVL/GPS uses and considerations, the technologies and their capabilities continue to advance. To maximize the benefits of these tools to provide data and information to field staff and winter maintenance managers, this synthesis compiled results from a survey of winter maintenance professionals and a review of relevant literature to understand the differences and operational considerations in various AVL/GPS systems. The survey received responses from more than half of the 39 Clear Roads member states describing recent experiences with using AVL/GPS systems to support winter maintenance operations.

In addition to describing AVL/GPS systems, auxiliary equipment and data uses, respondents described benefits and challenges in implementing AVL/GPS systems:

- Advantages from using AVL/GPS systems in winter maintenance activities included enhancing operations management, monitoring real-time conditions and providing traveler information. Respondents also identified winter maintenance material tracking, recording crashes and other incidents and vehicle diagnostics as important benefits of AVL/GPS use.
- Challenges encountered when using AVL/GPS systems in winter maintenance operations involved acceptance or buy-in of AVL/GPS systems by the workforce, management and others, data integrity and accuracy, and operation and maintenance issues.

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List of Abbreviations and Acronyms

AI	artificial intelligence
API	application programming interface
AV	autonomous vehicle
AVL	automatic vehicle location
CAN	controller area network
DOT	department of transportation
DOT&PF	Department of Transportation & Public Facilities (Alaska)
DOTD	Department of Transportation and Development (Louisiana)
DVR	digital video recorder
ETA	estimated time of arrival
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
INDOT	Indiana Department of Transportation
IOO	infrastructure owner-operator
LOS	level of service
MDSS	maintenance decision support system
OBU	on-board unit
ODOT	Ohio Department of Transportation
OEM	original equipment manufacturer
PennDOT	Pennsylvania Department of Transportation
RWIS	road weather information system
TMC	transportation management center
TxDOT	Texas Department of Transportation

Executive Summary

Automatic vehicle location (AVL) and Global Positioning System (GPS) technologies help state departments of transportation (DOTs) track vehicle location, identify engine maintenance needs and provide other support for winter maintenance programs. The Clear Roads Research Program has previously explored AVL/GPS uses and considerations, however the technologies and their capabilities continue to advance.

This synthesis project used a survey of winter maintenance professionals and a review of relevant literature to gather information on the current uses, benefits and challenges of AVL/GPS systems and auxiliary equipment. The survey received responses from more than half of the 39 Clear Roads members. Twenty of the 22 agencies that responded to the survey currently use AVL/GPS systems to automate data collection for winter maintenance operations. The two agencies not currently using AVL/GPS systems are interested in exploring the technologies or actively investigating for imminent implementation.

Survey respondents described vehicle fleets and equipment outfitted with AVL/GPS systems, auxiliary equipment and the range of data produced from the systems before assessing the benefits and challenges of using AVL/GPS equipment for winter maintenance.

Vehicle Fleets with AVL/GPS Systems

While the primary focus in the survey was heavy-duty plow-equipped fleets, state DOTs also equip additional equipment and vehicle types with AVL/GPS systems. Details of the range of vehicles equipped with AVL/GPS systems in responding states are provided in Appendix B.

Most states indicated that all or nearly all their snowplow fleets are — or soon will be — equipped with AVL/GPS systems. Identified truck models, in order of popularity, included:

- International (17 agencies).
- Freightliner (12 agencies).
- Mack (eight agencies).
- Western Star (seven agencies).
- Sterling (five agencies).
- Peterbilt (three agencies).
- Volvo (three agencies).

In addition to heavy-duty plow-equipped fleets, 13 states reported varying degrees of AVL/GPS use in light-duty vehicles such as passenger cars and small pickup trucks. Other agencies have installed AVL/GPS in light-duty vehicles in a more limited manner.

Other large vehicles and smaller equipment equipped with AVL/GPS systems include:

- Graders and sanders.
- Loaders and tractors.
- Message boards.
- Mowers and herbicide sprayers.
- Paint and bridge inspection trucks.
- Snowblowers.
- Specialty trailers.
- Sweepers and vacuum trucks.
- Woodchippers.

AVL/GPS Systems

Most agencies use AVL/GPS systems from three manufacturers: Geotab (nine agencies), Parsons (three agencies) and Samsara (eight agencies). Equipment may be leased or owned, and agencies pay monthly or annual fees for cell service subscriptions, data storage and/or service contracts.

Many agencies use just one make or model of AVL/GPS system. Of those that use more than one make or model, several agencies do not experience any issues using multiple systems while two others experience some difficulties in using more than one provider.

Nine state DOTs have made no systemwide changes in AVL/GPS providers, while others have switched providers. Of 11 agencies describing AVL/GPS provider changes, five have converted to Samsara and four changed to Geotab.

Many agencies plan to add more AVL/GPS units to winter maintenance fleets or other equipment such as graders and off-road equipment.

System Installation and Maintenance

Seven states install and maintain their agencies' AVL/GPS systems. The remaining 13 responding states share responsibility for installation and maintenance with the vendors. Installation and maintenance challenges were not prevalent among respondents, although some reported compatibility issues between vehicles and AVL/GPS systems.

Most respondents reported generally low failure rates of AVLGPS systems. Issues with firmware updates, cameras failing and cellular connection errors were cited by some DOTs. When systems need repair, downtime is minimal to a week or two, according to responding states. Many states keep spare parts or devices on hand to minimize downtime.

Similarly, most respondents indicated the costs of repair are not an issue, negligible or not substantial. Many states referenced vendor agreements such as service and equipment contracts, leases and warranties in avoiding or minimizing costs. All respondents reported positive vendor responsiveness when seeking to address AVL/GPS system repairs or failures.

Auxiliary Equipment

A variety of auxiliary equipment used in winter maintenance can be integrated with AVL/GPS systems including:

- *Dashboard cameras*. Most respondents indicated using some combination of front and rear dashboard cameras (dashcams) and some plan to expand usage of dashcams in winter maintenance plow trucks.
- *Material spreader controllers*. All but one of the responding states currently using AVL/GPS systems also use auxiliary spreader controllers. Certified Power Solutions and FORCE America were the most common manufacturers cited by respondents.
- *Mobile data terminals or computers.* Six agencies use mobile data terminals or computers in winter maintenance trucks.
- *Pavement and weather sensors.* Fourteen responding agencies use either pavement sensors, weather sensors or both in conjunction with their AVL/GPS systems.

- *Plow controllers or position sensors*. Eight agencies use plow controllers or position sensors in conjunction with their AVL/GPS systems.

Many agencies have not encountered difficulties installing or connecting auxiliary equipment to AVL/GPS systems. Other respondents reported a variety of issues with integration, including calibration of plow sensors, insufficient truck cab space, and device and firmware updates. Operational challenges such as vendor proprietary issues and third-party cameras were also mentioned.

Uses and Management of AVL/GPS Data

AVL/GPS systems and auxiliary equipment generate a range of data for a variety of uses. While many respondents did not report issues with data accuracy, others identified AVL/GPS data accuracy issues associated with material application rates or reporting, and a few respondents noted GPS location challenges.

Monitoring real-time conditions. Over half of the respondents use AVL/GPS systems for monitoring and reporting on temperature. Slightly fewer than half monitor and report on road conditions and only two states report on humidity values.

Real-time operations tracking. The most common real-time operational parameters tracked by AVL/GPS systems are vehicle location and diagnostics, and the time roadways were plowed and the material used. Less common data uses included asset utilization, tracking idling time and identifying crashes and speeding. Several agencies are interested in reporting on material usage as a future use of AVL/GPS systems.

Planning and operational analysis. In addition to supporting operations in real time, most respondents use AVL/GPS data for material usage tracking and analysis, followed by analyzing operations after winter weather events. Other uses included using the data for end-of-the-season after-action reviews, in research projects and to explore vehicle electrification. Several agencies are interested in expanding data uses for maintenance management system tracking functions like driver activities, preventative maintenance scheduling, and creating work orders that tie labor, equipment and materials together by route.

Data sharing. Image and video data are shared only privately by several states, but many provide plow location data through agency traveler information systems (511 sites). Some states provide still images in conjunction with plow location data when criteria such as traveling speed and location on state-maintained routes are met.

Data Collection and Management

In remote areas, inconsistent cellular coverage creates difficulties with data collection and transfer for several responding agencies. Solutions to overcome rural connectivity issues included equipping plows with Starlink or storing bulk data until cell service is restored and then uploading the data. A few states experience other issues with migrating data to and from AVL/GPS systems but generally are finding solutions.

Storing and managing AVL/GPS system data can be the responsibility of agency staff such as maintenance or fleet mechanics, and staff providing IT services or monitoring asset management. In many states, vendors are partially or solely responsible for managing AVL/GPS data. Similarly, data is stored on agency or vendor servers, or cloud-based storage provided by a vendor on agency servers.

Benefits and Challenges

State DOTs enjoy several advantages from using AVL/GPS systems for winter maintenance, such as operations management, monitoring real-time conditions and providing public traveler information. States also identified winter maintenance material tracking, recording crashes and other incidents and vehicle diagnostics as important benefits of AVL/GPS use.

Challenges encountered when using AVL/GPS systems in winter maintenance operations mainly fell into one of three categories:

- Acceptance or buy-in of AVL/GPS systems by the workforce, management and others such as unions, management and vendors (nine agencies). Counteracting concerns that "big brother" is watching was mentioned by a few respondents.
- Data integrity and accuracy issues (eight agencies) included plow position sensing and material data.
- Operation and maintenance issues (10 agencies) related to installing and maintaining systems and systems going offline for reasons such as a gap in cell coverage.

Respondents identified lessons learned and best practices in using AVL/GPS systems for winter maintenance. Seven agencies offered suggestions related to AVL/GPS system management, such as identifying a product champion, prioritizing data to collect, and establishing standards and policies prior to implementation. Gaining acceptance by operators, others in the agencies and the public was also mentioned by several states.

Examining the Literature

A literature search examined in-process and published research and other resources that address AVL/GPS technologies used by state DOTs for winter maintenance. Results of the literature search are presented in these categories:

- *Previous Clear Roads Research.* Over the past 10 years, Clear Roads' examination of the use of AVL/GPS in winter maintenance has included wide-ranging uses of these technologies and more targeted applications, including how AVL/GPS can inform optimization of snowplow routes and establishment of plow cycle times.
- *National Research and Guidance*. The 2024 *NCHRP Research Report 1119: Automated Applications for Infrastructure Owner-Operator Fleets "*provides the current status of and barriers to the implementation and application of autonomous vehicles (AV) and other automated technologies that may potentially supplement or replace infrastructure owner-operator (IOO) fleets." Included in the report are brief examples that describe how DOTs have implemented automated functions such as AVL/GPS in snowplows to support winter maintenance operations.
- *State Research and Resources.* State resources address the use of AVL/GPS for snowplow location, weather conditions, camera interfaces and snowplow driver assistance.
- *Vendors and Manufacturers.* Websites for the vendors and manufacturers offering the AVL/GPS and auxiliary equipment referenced in this synthesis report are provided along with the *noted products* used by a responding agency.

1 Introduction

1.1 Background

Automatic vehicle location (AVL) and Global Positioning System (GPS) technologies are used by state departments of transportation (DOTs) for many purposes, including tracking vehicle location, assessing engine maintenance needs and supporting winter maintenance operations. While the Clear Roads Research Program has previously explored the range of AVL/GPS uses and considerations, the technologies and their capabilities continue to advance. Maximizing the benefits of these tools to provide data and information to field staff and winter maintenance managers requires understanding the differences in various AVL/GPS systems.

Clear Roads members requested this synthesis to identify the manufacturers and models of AVL/GPS equipment, spreader controllers, winter maintenance vehicles and other equipment used by member agencies; how successfully the equipment is integrating; and the usefulness and accuracy of the data generated with AVL/GPS systems.

1.2 Project Description

A two-part strategy gathered information for this synthesis:

- *Survey of winter maintenance professionals*. A survey of Clear Roads member states and selected members of the AASHTO Committee on Maintenance gathered information about experiences using AVL/GPS systems for winter maintenance operations. The survey sought information about a range of issues, including:
    - AVL/GPS systems used.
    - Auxiliary equipment integrated with AVL/GPS systems.
    - Data uses and accuracy.
    - AVL/GPS system assessment and best practices.
- *Literature search*. An examination of publicly available domestic resources and in-progress research supplemented survey findings.

1.3 Survey Response

The survey received responses from 22 state transportation agencies:

- Alaska
- Connecticut
- Delaware
- Iowa
- Kansas
- Louisiana
- Maine
- Massachusetts
- Michigan
- Minnesota
- Nebraska
- Nevada
- New Jersey
- Ohio
- Oklahoma
- Oregon
- Pennsylvania
- South Dakota
- Tennessee
- Vermont (partial response)
- West Virginia
- Wyoming

Survey questions are provided in Appendix A.

1.4 Organization of This Synthesis Report

Chapter 2 presents the survey findings regarding responding agencies' use of AVL/GPS systems for winter maintenance operations. AVL/GPS systems, the vehicles in which systems are installed and auxiliary equipment are described, AVL/GPS data uses and management considerations are presented, and benefits, challenges and lessons learned are summarized.

Chapter 3 supplements survey findings with a summary of relevant literature. The report's appendices contain the survey questions and more detailed descriptions of agency vehicles equipped with AVL/GPS systems.

While the survey conducted for this synthesis received responses from more than half of the 39 Clear Roads members, 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 in using AVL/GPS and auxiliary equipment to support and enhance winter maintenance safety and services.

2 AVL/GPS for Winter Operations

2.1 Background

Many state DOTs have used AVL/GPS systems in various contexts for several years. Of the 22 agencies responding to the survey, 20 currently use AVL/GPS systems to automate data collection for winter maintenance operations.

Respondents described the range of their experiences with AVL/GPS systems and several aspects of the AVL/GPS systems themselves, including:

- AVL/GPS-equipped vehicles.
- AVL/GPS systems.
- Auxiliary equipment.
- Uses and management of AVL/GPS data.
- Assessing AVL/GPS systems.

Louisiana Department of Transportation and Development (DOTD) and West Virgina DOT are not currently using AVL/GPS technologies but indicated interest, as described in Section 2.6, Agencies Interested in AVL/GPS Systems.

2.2 AVL/GPS-Equipped Vehicles

Survey respondents described the range of vehicles equipped with AVL/GPS systems. While the primary focus in the survey was heavy-duty plow-equipped fleets, respondents also identified additional equipment and vehicle types equipped with AVL/GPS. Survey responses for heavy-duty fleets and other vehicles and equipment are summarized, in turn, below.

Heavy-Duty Plow-Equipped Fleets

State DOT plow-equipped fleet sizes, percentage of the fleet or number of trucks equipped with AVL/GPS systems, and brands of trucks are presented in Table 1. Where models are not identified, respondents generally reported the use of various models or did not specify the models. This information is also summarized in Appendix B.

Most respondents indicated that all or nearly all their snowplow fleets are — or soon will be — equipped with AVL/GPS systems. Identified truck models, in order of popularity, included:

- International (17 agencies).
- Freightliner (12 agencies).
- Mack (eight agencies).
- Western Star (seven agencies).
- Sterling (five agencies).
- Peterbilt (three agencies).
- Volvo (three agencies).

Table 1. Agency Plow Fleets With AVL/GPS Systems

State	Heavy-Duty Plow-Equipped Fleet Count	Number/Percentage of Fleet With AVL-GPS	Truck Manufacturer and Model
Alaska	Not provided	More than 70 trucks	• International HV13 • Mack Granite
Connecticut	645	Currently 265 trucks; will be fleetwide in summer 2026	• Freightliner • Ford F-750 • International
Delaware	330	100%	• Freightliner • International
Iowa	920	100%	• International
Kansas	591	100%	• Freightliner • International • Sterling
Maine	430 (approx.)	100%	• Many different models
Massachusetts	2,847	44%	• Freightliner • International • Mack • Peterbilt • Volvo
Michigan	385 (approx.)	100%	• International • Western Star
Minnesota	893	97%	• Freightliner 114SD • International 7500 and 7600 • Sterling LT9511 and L8511 • Western Star 470SF, 47X and 49X
Nebraska	655	100%	• Freightliner 114SD • International 7600, SFA 6X4 and 7400 SFA • Sterling LT9500, T7500, LT9511 and LT7501 • Western Star 4700SF
Nevada	188	90%	• International 2574 • Mack RD688S • Peterbilt 357 and 367 • Western Star 4900, 4900FA, 4900SF and 49X
New Jersey	530	100%	• International 7400 and STF 4X2 • Volvo VHD64F
Ohio	1,650 (approx.)	100%	• Freightliner • International • Mack • Western Star

State	Heavy-Duty Plow-Equipped Fleet Count	Number/Percentage of Fleet With AVL-GPS	Truck Manufacturer and Model
Oklahoma	733	85% to 90%	• Freightliner • International • Western Star
Oregon	465	99%	• Volvo VHD
Pennsylvania	2500	100%	• Ford • International • Mack • Peterbilt • Western Star
South Dakota	328	90%	• Freightliner SD114 • International • Mack GU713 • Sterling
Tennessee	850	100%	• Freightliner • International • Mack
Vermont	254	100%	• Freightliner • International
Wyoming	374	85% (approx.)	• Freightliner 114SD (year models between 2011 – 2026) • International 7600 (2009) • Mack GR64R (2020, 2023); GUR64R (2018); GU713 (2014)

Additional Vehicles Equipped With AVL/GPS

In addition to heavy-duty plow-equipped fleets, almost all respondents identified various light-duty vehicles and other equipment outfitted with AVL/GPS systems. Only South Dakota DOT has no additional vehicle types equipped with these systems. Highlights of additional AVL/GPS-equipped assets are provided below. See Appendix B for a detailed presentation of these survey responses.

Light-Duty Vehicles

Thirteen states reported varying degrees of AVL/GPS use in light-duty vehicles such as passenger cars and small pickup trucks. In Connecticut, all light-duty vehicles will be equipped with AVL/GPS in 2026. Similarly, all vehicles in New Jersey and Nevada's entire light-duty fleet are AVL/GPS-equipped.

Other agencies have installed AVL/GPS in light-duty vehicles in a more limited manner. In Oklahoma, the pickup trucks of superintendents who supervise snowplow operations are AVL/GPS-equipped; similarly, Pennsylvania is currently installing these systems on foreman crew cabs and managers' vehicles.

Wyoming provides AVL/GPS capability in light-duty vehicles in several ways. The Motorola radios installed in many vehicles also have AVL capability; vehicles in the agency's GIS/ITS and maintenance fleets may also have AVL systems. Other vehicles are equipped with Samsung tablets with cellular service that can also be used as an AVL system.

Other Vehicles and Equipment

Responding states identified other large vehicles and smaller equipment that are equipped with AVL/GPS systems, including:

- Graders and sanders
- Loaders and tractors
- Message boards
- Mowers and herbicide sprayers
- Paint and bridge inspection trucks
- Snowblowers
- Specialty trailers
- Sweepers and vacuum trucks
- Woodchippers

2.3 AVL/GPS Systems

Survey respondents described the AVL/GPS systems their agencies currently use and any plans for systemwide changes in AVL/GPS providers. Survey responses are organized into two topic areas:

- AVL/GPS systems in use, including multiple systems use and expansion plans.
- Reasons for changing AVL/GPS providers.

AVL/GPS Systems in Use

Most responding agencies use AVL/GPS systems from three manufacturers:

- Geotab (nine agencies).
- Parsons (three agencies).
- Samsara (eight agencies).

Many respondents did not specify the system models their agencies are using. Other AVL/GPS systems included custom-developed software (*Ohio*), Verizon and other mobile providers (*Alaska* and *Wyoming*), and several other manufacturers used by Wyoming DOT.

Agencies also described monthly or annual fee structures. AVL/GPS systems, numbers of units and system fees are summarized in Table 2, followed by respondent comments relating to the use of multiple systems and plans to expand the use of AVL/GPS.

Additional vendor information is provided in Table 8 and Table 9 and in Chapter 3, Examining the Literature.

Table 2. Agency AVL/GPS Systems and Fees

State	Manufacturer, Model and Number of Units	System Fees
Alaska	• Samsara dashcams (over 70 units). • Verizon AVL (number unknown).	Annual service and license fees for Samsara.

State	Manufacturer, Model and Number of Units	System Fees
Connecticut	• Parsons (265). • Samsara (50 as of February 2026).	• Parsons: Annual subscription cost spread over the year. • Samsara: Monthly subscription cost. • Monthly cell and service access. • Maintenance decision support system (MDSS) subscription through AVL provider.
Delaware	• Geotab GO9 with Public Works option (330 units). • Geotab Rugged (7 units).	Standard monthly fees.
Iowa	Samsara (all winter operations equipment).	• Samsara: Annual licensing fees. • Most equipment owned by company.
Kansas	Samsara (610 units).	Annual fees.
Maine	Samsara (430 units).	• Modem fees for internet connections. • Service agreements. • Other support.
Massachusetts	Geotab GO9 (all installations).	• Monthly per-vehicle fees include all monitoring and are generally $20 or less. • Devices are leased.
Michigan	• Parsons MDC-006 (over 400 units). • Parsons MDC-007B (20 units).	Monthly fees: • Cell coverage per unit. • AVL data storage. • Project management and technical assistance.
Minnesota	• Geotab GO Anywhere (725 units). • Geotab GO9 (1,984 units). • Geotab GO9B (1,349 units). • Geotab Custom Vehicle Device (361 units).	Monthly subscription fee.
Nebraska	Samsara HW-VG55-NA (655 snowplows and 54 light-duty vehicles).	Standard monthly fees.
Nevada	Geotab GO9 and GO9B (1,687 units).	• Monthly subscription per unit. • Fees for more involved installations such as plow trucks and sweepers.
New Jersey	• Samsara VG34 (25 units including 3 in plow trucks). • Samsara VG54 (2386 units including 522 in plow trucks and 160 for winter contractors). • Samsara VG55 (659 including 5 in plow trucks and 592 for winter contractors). • Samsara AG26 and AG46 (74 on non-vehicle assets). • Samsara AG51, AG52 and AG53 (196 on non-vehicle assets).	Annual fee per unit.

State	Manufacturer, Model and Number of Units	System Fees
Ohio	• Custom Developed Software (on approximately 1,650 dump trucks). • Geotab (unknown number of smaller fleet vehicles).	• Monthly maintenance and support fees. • Monthly cellular plans per unit.
Oklahoma	• Samsara VG54-NA (114 units). • Samsara VG54-NAH (374 units). • Samsara VG55-NA (217 units).	Monthly fee $480 per unit.
Oregon	• Geotab GO9 (2,035 units). • Geotab GO Rugged (2 units).	Standard monthly subscription.
Pennsylvania	Geotab (over 4,000).	Monthly service fee through AT&T.
South Dakota	• Parsons MDC004 (120 units). • Parsons MDC006 (208 units).	Two-year warranty up front which transfers to a maintenance contract with vendor for the life of the initial contract.
Tennessee	• Geotab GO Anywhere asset tracker (4,227 units). • Geotab GO Focus dash cam (2,875 units). • Geotab GO Focus Plus 360-degree visibility (236 units). • Geotab NFC Readers (6,446 units). • Geotab GO9 fleet asset tracker (2,219 units on nonpowered equipment).	Standard monthly fees per unit.
Wyoming	• PreCise/FORCE America controllers (over 250 units). • AVL-equipped Motorola Radios equipped with AVL's (unknown number but considerably higher than plow count). • Samsung Tab A7 Lite, A9 Plus, A11 Plus tablets with either AT&T, First Net, Verizon or T-Mobile Service (over 100 units). • John Deere HD, JD Link (around 30 units). • Caterpillar VisionLink (74 units).	• PlowOps (NeoTreks) charges $12.50 per device for AVL. • PreCise/FORCE America annual fees for each truck plan.
Vermont	Geotab GO9 (over 600 (all) units).	Standard monthly fees.

Respondents provided these additional comments on their AVL/GPS systems:

- Maine DOT noted that while the whole fleet is equipped, the systems are primarily used for monitoring and health of equipment and not yet as much for materials reporting.
- New Jersey DOT's AVL/GPS units in contractor vehicles are for location only and plug into 12-volt accessory outlets.
- Tennessee DOT provided additional details on the agency's AVL/GPS equipment:
    - *Geotab GO Anywhere* asset trackers provide mileage and location data.
    - *Geotab GO Focus* dash cams are "safety cameras" that record collision data including still images of road conditions.

- *Geotab GO Focus Plus* are cameras that record 24/7 and are installed on around 200 dump trucks and highway response units to monitor road conditions.
- *Geotab NFC (near-field communication) Readers* allow drivers to scan their cards to monitor shift work, route coverage and driver safety.
- *Geotab GO9* fleet asset trackers are used on non-powered assets such as brine trailers and message boards.

Expanding AVL/GPS Use

Seven responding agencies do not have plans to expand the use of AVL/GPS technologies on winter maintenance vehicles (*Michigan, Nebraska, New Jersey, Ohio, Oregon, South Dakota* and *Tennessee*). Nevada DOT is discussing expanding AVL/GPS based on data already collected but has not finalized plans.

Seven other agencies plan to add more AVL/GPS units to winter maintenance fleets or other equipment. Wyoming DOT's goal is to have every plow truck, maintenance fleet unit pickup and Wyoming Highway Patrol Trooper outfitted with the Motorola Radio based position unit. Oklahoma DOT plans to equip all fleet vehicles with AVL/GPS without front cameras.

Other vehicles and equipment respondents plan to outfit with AVL/GPS systems fall into two categories:

Winter Maintenance Fleets

- All fleet vehicles, including remaining snow and ice fleet not currently equipped (*Connecticut*).
- All salt spreaders and tankers are currently being equipped; have not yet implemented contracted non-material spreaders (plows) (*Massachusetts*).
- New tow plows and trucks; all fleet vehicles (*Oklahoma*).

Other Maintenance Equipment

- Graders, sanders and other material application vehicles; potentially non-winter maintenance equipment as resources allow (*Alaska*).
- Heavy-duty equipment such as high-reach vehicles, knuckle boom trucks and possibly paint vehicles (*Iowa*).
- Off-road equipment (*Oregon*).

Some responding agencies plan to expand how AVL/GPS data is used; these responses are discussed in Section 2.5, Uses and Management of AVL/GPS Data.

Using Multiple AVL/GPS Systems

Eight responding agencies use just one make or model of AVL/GPS system, including the Iowa respondent, who noted that using only Samsara units on their heavy-duty fleets provides standardized data, allows for consistent installations and certainty around spare part availability.

Three agencies use more than one system without any challenges:

- *Connecticut* uses two systems separately for different operational needs.
- *Michigan* noted using Parsons MDC-006 in snowplows and herbicide vehicles, while the Parsons MDC-007B small GPS unit is used on woodchippers and some tractors to show location.

- *Oklahoma* has had no issues with multiple systems and that the equipment upgrades are simple.

Two other agencies indicated challenges with using more than one AVL/GPS system:

- *Ohio* noted using different devices required logging into different websites.
- *Wyoming*'s data integration into fleet management and tracking systems can cause complications when multiple staff are working on different angles of the same problem, and device upkeep can be a challenge.

Changing AVL/GPS Providers

Nine survey respondents have made no systemwide changes in AVL/GPS providers (*Kansas, Maine, Michigan, Ohio, Oklahoma, Oregon, Pennsylvania, Wyoming* and *Vermont*). Others described AVL/GPS system changes and some provided reasons for changing providers. Out of 11 state DOTs describing AVL/GPS provider changes, five converted to Samsara and four changed to Geotab. Survey responses regarding changing AVL/GPS providers are summarized in Table 3.

Table 3. Agency Changes in AVL/GPS Providers

State	Previous System Used	New System and Reasons for Change
Alaska	Verizon	Slowly converting to Samsara for additional automation and integration features.
Connecticut	Parsons	Currently changing to Samsara due to Department of Administrative Services requirement to install in all vehicles (not just snow and ice) to track fleet performance and compliance of drivers with safety requirements.
Delaware	• Thingtech • NetworkFleet	Current provider is Geotab. Reasons for change: • Thingtech: poor performance. • NetworkFleet: Didn't provide snow-relevant information.
Iowa	• Location Technologies Inc. • Skyhawk (used Cypress modems) • Cypress (continued with Cypress modems)	After using AVL/GPS for nearly 15 years, started using Samsara in 2024.
Massachusetts	• Nextel cellphones • Geotab under AT&T as the reseller	Currently use Geotab with Advantage Asset Tracking as the reseller.
Minnesota	• AmeriTrak for snowplows • Verizon for everything else	Current provider is Geotab.
Nebraska	Parsons	Switched to Samsara: • Lower cost • Easier installation • More capability

State	Previous System Used	New System and Reasons for Change
Nevada	Verizon GPS system	Switched to Geotab.
New Jersey	Basic GPS system	Switched to Samsara because Basic system only provided location information.
South Dakota	Parson MDC004	Slowly upgrading to the Parsons MDC006 for: • Faster processor. • Better internal Sierra Wireless modem. • Larger hard drive.
Tennessee	Samsara	Transitioning to Geotab. Samsara issues: • An external route monitoring system was needed to monitor entire dump truck fleet connectivity. • Was not offered updated devices when units became outdated and operations problematic. • Lack of transparent billing. • Route coverage and monitoring.

AVL/GPS System Installation, Maintenance and Operation

Installing and keeping equipment operating properly can present challenges for winter maintenance programs. State agency respondents described operational issues related to AVL/GPS systems in three areas:

- Varying responsibilities for system installation and maintenance.
- Installation and maintenance challenges including system failure rates and compatibility issues.
- System repair considerations, including turnaround time, repair costs and vendor responsiveness.

Survey responses describing auxiliary equipment and related operational issues are summarized in Section 2.4, Auxiliary Equipment.

System Installation and Maintenance Responsibilities

For slightly more than one-third of respondents, both installation and maintenance of AVL/GPS systems are the sole responsibility of the agency. For the remaining respondents, this responsibility is shared in varying ways between the agency and vendor. All responding agency practices are summarized below.

Agency Staff. Seven states, including Delaware, Minnesota, Nebraska and Vermont, noted that internal agency staff both install and maintain AVL/GPS systems. Others provided more specific descriptions:

- State Equipment Fleet staff install and maintain AVL/GPS systems and ITS staff also help maintain systems (*Alaska*).
- Garage mechanics received train-the-trainer install training from Samsara and DOT staff install and maintain all systems (*Iowa*).
- Depending on the type of AVL/GPS system, installation and maintenance are done by DOT Emergency Communications, equipment personnel or Traffic Management Center employees trained in system deployment and installation (*Wyoming*).

Both Agency Staff and Vendors. The remaining 13 states described sharing AVL/GPS system installation and maintenance responsibilities in four different arrangements:

- Both installation and maintenance are performed by both agency and vendors in Nevada and three other states:
    - Parsons equipment is installed and maintained by the vendor or contractor while Samsara equipment may be installed and maintained by a vendor or DOT staff (*Connecticut*).
    - Geotab's install team, including contractor Boston GPS, and DOT mechanics install systems and Geotab is responsible for failed devices (*Massachusetts*).
    - Vendor-supplied contractors install most heavy fleet systems and DOT technicians install systems on light-fleet vehicles. System repairs are primarily handled in-house (*Oregon*).
- Both the agencies and vendors install equipment; only the agencies maintain equipment in Maine, Oklahoma and two other states:
    - Truck builders install most systems, though some are done in-house (*Pennsylvania*).
    - Samara did the original installations. When trucks turnover, DOT staff reinstall the systems. The Bureau of Maintenance maintains the website and data and the mechanics swap the gateways (*Kansas*).
- Third-party vendors install systems and agencies maintain them in Michigan and New Jersey. At Tennessee DOT, a third-party contractor provided by Geotab installs the systems and DOT garage staff are trained to install and diagnose issues. Vehicle supervisors are responsible for monitoring the systems.
- In two states, the agency installs and vendors maintain AVL/GPS systems:
    - In-house installations are maintained through software contracts. The agency completes the initial equipment installation and replaces broken hardware; the vendor addresses software-related maintenance (*Ohio*).
    - The agency installs equipment and performs minor repairs while the vendor repairs internal hardware (*South Dakota*).

Installation and Maintenance Challenges

Survey questions queried respondents regarding challenges installing or maintaining AVL/GPS systems. State DOT descriptions of compatibility issues between vehicles and AVL/GPS systems, and AVL/GPS system failure rates are summarized below.

Vehicle Compatibility Challenges. Ten respondents indicated that vehicle makes or models do not pose any challenges when installing or operating AVL/GPS systems. Others identified various compatibility issues between vehicles and AVL/GPS systems, as summarized in Table 4.

Table 4. Challenges With Compatibility of Vehicles and AVL/GPS Systems

Challenge	State and Description
Cab Size or Design	*Connecticut*. Mounting rear computer plate and equipment, including mounting behind the seat caused issues with freightliners. *Oklahoma.* Finding places to hide equipment varies with cab designs.

Challenge	State and Description
Manufacturer or Proprietary	*Delaware*. Truck manufacturers seem to discourage fleet owners from diagnosing their own equipment, necessitating sending it to the dealer. *Tennessee*. Heavy equipment must be in read-only mode to prevent interference with manufacturer software, which prevents gathering some diagnostic data.
Older Equipment	*Oregon.* Older, often third-party devices do not meet current controller area network (CAN) communication protocols, causing battery drain issues, faulty AVL/GPS communication with the vehicle, malfunctions in other devices or network static causing vehicle controllers to go offline. Examples of problematic devices: • Jamar distance measuring devices. • AutoLink 1 wireless adapters. • Some crane or power take-off auxiliary equipment controllers on service trucks.
Physical Connections	*Kansas.* Vendors put gateway or diagnostic hook-ups in varying locations e.g., cables for material spreader controllers were 6 inches too short so gateway hookup was moved to back of cab. *Massachusetts.* Most vehicles have a six- or nine-pin adapter that allows connection of system to the engine control module; older trucks may have a three-wire setup. The GPS vendor usually knows installation requirements for particular makes and models. *Nevada.* Some older trucks have a simple three-wire GPS device installed, which only provides GPS and spreader data but no engine data.

Failure Rates

Some respondents noted that AVL/GPS system failure rates were unknown (*Alaska, Nevada, Ohio* and *Pennsylvania*) or not applicable (*New Jersey*). In Maine, no system failures have been reported to date and eight other states indicated minimal or low system failure rates:

- One gateway failed in last two years (*Kansas*).
- One or two percent failure rate (*Iowa, Massachusetts* and *Nebraska*).
- Four to five percent failure rate (*Delaware* and *Minnesota*); Wyoming reported a low failure rate for PreCise/FORCE America and Motorola AVLs, though 24 of the 480 tablets have failed.
- Oregon DOT has experienced minimal device failure but experiences increasing issues with firmware updates.

Four other states reported higher rates of AVL/GPS system failure:

- *Tennessee* experiences an approximate failure rate of 10%, mostly attributed to cameras.
- *Michigan* has had an estimated 20% failure rate over the past 4.5 years.
- A 20% failure rate in *South Dakota* is mainly due to cellular connection errors.
- While *Connecticut* has not kept metrics on failure rates, the agency reports “substantial downtime” on some equipment.

AVL/GPS System Repair Considerations

Agencies using AVL/GPS systems in their winter maintenance operations experience varying system downtime, repair costs and responsiveness of vendors involved in repairs. Survey responses discussing each issue are summarized, in turn, below.

System Downtime. Some survey respondents described minimal system downtime (*Alaska, Ohio* and *Pennsylvania*). Maine DOT has not yet experienced downtime and the Kansas respondent noted not experiencing any issues as Samsara maintains the web site.

Several agencies rely on keeping a supply of spare system parts or devices to avoid or minimize downtime (*Iowa* and *Massachusetts*) and provided these details:

- Most repairs are swaps with spares kept on-hand and down time is minimal--typically a few days at most (*Minnesota*).
- The agency keeps spare AVL/GPS units for immediate replacements and sends the faulty units for repair which then become spares upon their return. Turnaround time to receive repaired units varies with the issue found (*Michigan*).
- Keeping extra inventory incurs monthly fees but minimizes downtime; replacements usually ship within a week (*Tennessee*).

Four states described one- to two-week system downtimes and provided additional detail on varying circumstances:

- Replacement hardware typically takes a week to receive and another week or two for agency staff to install (*Nebraska*).
- Several devices are currently offline and the agency is consulting the vendor. Warranty replacement typically takes one to two weeks (*Nevada*).
- Agency staff resolve some issues through on-the-spot minor repairs. If vendor attempts to remotely resolve internal hardware problems are unsuccessful, agency staff will send the unit to the vendor with a turnaround time of up to two weeks (*South Dakota*).
- Repairs are generally quick depending on parts availability. Tablet warranties include a 5-day turnaround and another two days for configuration and delivery (*Wyoming*).

Additional comments on AVL/GPS system downtime included:

- Connecticut DOT has experienced difficulties with awareness and communication regarding when trucks went down and who was responsible for arranging the repair work.
- Delaware DOT's AVL system downtime issues were not considered problematic, as trucks continued to perform their required functions and repairs are made when trucks are out of service.

Repair Costs. Respondent feedback on repair costs varied in scope. Most, however, indicated the costs of repair are not an issue, negligible or not substantial.
In Maine, there had not been issues related to repair; the Iowa respondent reported that repair costs have been limited, noting that a bad or damaged cable will occasionally need replacement. Similarly, the Pennsylvania respondent reported no repair issues unless the equipment was tampered with.

Quantified costs were not generally identified by respondents, though the Kansas DOT respondent noted that new gateway costs are around $80. Wyoming DOT's AVL/GPS system repair costs vary.

Many states referenced vendor agreements such as contracts, leases and warranties when attempting to avoid or minimize costs, as summarized in Table 5. While agreement categories are distinctly presented, overlap exists. For example, contracts may refer to task or service arrangements with leased or purchased equipment. Leased equipment may or may not include service contracts. Some respondents reported no costs while others indicated minimal or varied costs, as described in the comments in Table 5.

Table 5. AVL/GPS System Repair Agreements

Agreement Type	State and Comments
Contract	*Minnesota.* Service subscription covers repair costs. *Nebraska.* Replacement of failed units included in Samsara contract. *Ohio.* Maintenance and support fee covers costs.
Lease	*Alaska.* While the equipment is not purchased, the agency pays for services and shipping. There is agency interest in establishing a permanent workflow for repair/replacement of faulty or damaged units. *Massachusetts.* Equipment is leased and Geotab is responsible for maintaining working devices.
Warranty	*Connecticut.* Costs vary depending on warranty coverage and scope of repair needed. Most costs are for vendor field visits. *Delaware.* Vendor provides components at no charge. *Michigan.* • No cost (other than DOT staff time) to repair failed units. • While failure rates for plow blade sensors or other components are not tracked, repair costs are low. • Equipment within the two-year warranty window is replaced by the vendor. *Nevada.* All devices are covered under a lifetime warranty including free replacement. *Tennessee.* Devices are currently covered under replacement warranty. *New Jersey.* Yearly fee covers gateway cost, including replacement of malfunctioning units. *Oregon.* Repair costs are limited to internal labor costs due to warrantied devices.

Vendor Responsiveness. All state DOTs reported positive vendor responsiveness when seeking to address AVL/GPS system repairs or failures. While informal ratings and comments are summarized in Table 6, some respondents offered additional comments about specific vendors:

Geotab

- The vendor is quite responsive to the agency, but contracted maintenance vendors have complained about installations as they "often have an axe to grind" (*Massachusetts*).
- Weekly meetings with the vendor and authorized reseller provide for very good responsiveness (*Oregon*).
- The vendor provides a dedicated support team and 24/7 customer support for each account (*Tennessee*).

Parsons

- The vendor is generally very responsive when notified of an issue (*Michigan*).

Samsara

- The vendor is very responsive to occasional technical issues; otherwise, DOT staff handle repair or downtime issues (*Iowa*).
- The vendor took weeks to months to respond to issues, often with no resolution (*Tennessee*).

Table 6. Informal Vendor Responsiveness Ratings

Vendor Responsiveness	State and Comments
Very Good	*Iowa, Michigan, Minnesota, Ohio, Oregon, Tennessee* *Alaska*. Vendor currently implementing the system and is very responsive; regular service team responsiveness is unknown. *Pennsylvania*. Agency has weekly meetings with vendor, who is always a phone call or email away. *South Dakota*. Contract has a 24-hour response clause and vendor is very quick to respond. *Wyoming*. Generally quick with an hour response time for tablets.
Good	*Delaware, Massachusetts* *Connecticut*. Vendor is responsive to schedule a repair, however replacement part delays can create extended outages. *Maine*. Vendor has a wide geographic presence, so is easily accessible. Nevada. Vendor usually responds within 24 hours.
Mostly Good	*Nebraska*

2.4 Auxiliary Equipment

A variety of auxiliary equipment used in winter maintenance can be integrated with AVL/GPS systems. Survey questions explored the range of auxiliary equipment used and how well it integrates with the AVL/GPS systems and vehicles. Summarized below are survey responses in two primary categories:

- Auxiliary equipment used, including:
  - Dashboard cameras
  - Material spreader controllers
  - Mobile data terminals or computers
  - Pavement and weather sensors
  - Plow controllers or positions sensors
- Installation and operational compatibility issues

Equipment Used

Survey respondents identified auxiliary equipment used in conjunction with AVL/GPS systems in six categories, summarized in Table 7. Following Table 7, the details provided by state DOT respondents in each category of auxiliary equipment are summarized and annotated, where possible, with vendor website links and product descriptions. Vendor websites are also provided in Chapter 3.

In addition to the auxiliary equipment identified in the table below, since 2021 Connecticut DOT has provided digital alerts through the HAAS Alert Safety Cloud platform. The Safety Cloud platform, which can be activated for Samsara users on their vehicles without any additional hardware, warns drivers of

various hazards on the road such as such as roadside assistance and emergency vehicles. Pennsylvania DOT is working on a connection between emergency lights and Google maps or other apps.

Table 7. Auxiliary Equipment Used by Agencies

State	Dashboard Cameras	Material Spreader Controllers	Mobile Data Terminals	Pavement Sensors	Plow Controllers or Position Sensors	Weather Sensors
Alaska	√	√			√	
Connecticut	√	√	√	√		√
Delaware		√				
Iowa	√	√	√	√	√	√
Kansas	√	√				
Maine	√	√	√	√		√
MassDOT	√	√				√
Michigan	√	√	√	√		√
Minnesota	√	√	√	√		√
Nebraska	√	√		√	√	
Nevada	√	√		√	√	
New Jersey		√				
Ohio	√	√		√		√
Oklahoma	√	√			√	
Oregon		√		√	√	
PennDOT	√	√	√		√	√
South Dakota	√	√	√		√	√
Tennessee	√				√	√
Wyoming	√	√		√	√	√
Total	**16**	**18**	**7**	**10**	**10**	**11**

Dashboard Cameras

Most respondents use some combination of front and rear dashboard cameras (dashcams). Delaware DOT does not use cameras but hopes to use forward-facing dashcams in the future. Some respondents did not provide manufacturers or models (*Alaska, Maine, Minnesota* and *Pennsylvania*). All Alaska Department of Transportation and Public Facilities (DOT&PF) plow trucks have front dashcams and a few have rear exterior cameras. Maine DOT has only a few trucks equipped with cameras and Minnesota DOT's plow trucks have front-facing cameras.

Four states plan to expand usage of dashcams in winter maintenance plow trucks (*Kansas, Minnesota, Oklahoma* and *Vermont*). Minnesota DOT is considering artificial intelligence (AI) cameras and rear-facing cameras, while Oklahoma DOT is exploring rear-facing cameras. Vermont Agency of Transportation is interested in forward-facing camera interfaces.

Dashcam manufacturers and models identified by respondents are presented in Table 8, including selected descriptions from manufacturers' websites and state user comments.

Table 8. Dashboard Cameras

Manufacturer	Product/Model	Product Description	State and Comments
Dakota Micro, Inc.	EnduraCam CVBS 92° NTSC Camera (DMEC-LC)	Connects directly with all Dakota Micro monitors and wireless units and also works with a variety of third-party displays via adapters.	*Massachusetts.* Trial use of cameras with a Certified Cirus (Certified Power Solutions) SpreadSmart controller, including a new 10-inch HMI display (see Figure 2). replacing the older 7-inch display (see Figure 1). New displays are specified for all new equipment purchases and retrofit of existing agency-owned spreader fleet.
FORCE America, Inc.	SSC6100 CAN Bus Spreader Control System (see page 6 of the PDF)	Embedded within the 10-inch color LCD, this controller comes fully equipped with camera integration, antenna and PreCise MRM cellular and GPS technologies.	*Wyoming*. Front-facing cameras using PreCise/FORCE America controllers.
Geotab, Inc.	GO Focus and GO Focus Plus AI forward-facing dash cam	• Protects driver privacy by recording only road-facing footage during key driving events. • Processes encrypted data locally, limiting driver exposure while still delivering the safety insights fleets need.	*Tennessee:* • Front-facing GO Focus records safety triggered events only. • GO Focus Plus records 24/7 for select route monitoring of snowplow trucks.
i-PRO Co., Ltd.	All-in-one compact dome camera with AI engine and IR-LED	• 2MP compact dome camera. • Up to 2 Edge AI analytic apps. • Wide angle of view (horizontal 132°). • Built-in IR-LED (21m/69ft) and microphone. • IP66, IK10 certified. • Built-in FIPS 140-2 Level 3 Compliant SecureElement (EdgeLock SE050F NXP Semiconductors).	*Connecticut:* • Parsons contract recently expired. • Moving to i-PRO, which branched off from Panasonic (see Figure 3 for product details).
Microseven Systems LLC	M7D77-POE 1080p IP PoE Wide-Angle Camera (150°)	• Maximum resolution up to 1080p, with a maximum resolution of 1920x1080. • Uploads alarm snapshot and 25-second video clip to an FTP server and sends accompanying email. • Sends scheduled image snapshots to an FTP server. • Allows up to six users viewing simultaneously.	*Ohio*. Uses Microseven Systems HD camera mounted as a front-facing camera on a truck cab's headliner. **Note**: Among the capabilities noted in the product description, Ohio DOT only sends scheduled image snapshots to an FTP server.

Manufacturer	Product/Model	Product Description	State and Comments
Microsoft	LifeCam Studio	• Features TrueColor Technology with face tracking to remain bright and colorful in virtually all lighting conditions. • ClearFrame Technology provides smooth and detailed footage.	*Michigan, South Dakota*. Front-facing camera.
MS Foster & Associates	Voyager Vehicle Camera System	• Engineered and tested to perform in demanding conditions. • Can be installed as a rear camera, side-body camera or 360° system. • Rearview vehicle camera system displays video in either color or black and white with 150° viewing angle. • Powered with a 12-volt DC battery.	*Michigan.* Rear-facing camera; Model VCMS24b (not found on manufacturer webpage).
Pro-Vision	Cameras	Camera models include forward- and side-facing, dome style, 360° and low-profile cameras.	*Iowa*. Rear-facing camera; model not specified.
Samsara, Inc.	Dual-facing AI dash cam	• Captures HD video and identifies risks in real-time with edge computing and in-cab audio alerts. • Analyzes video and safety data using the connected operations cloud from any device.	*Iowa*
Samsara, Inc.	Front-facing AI dash cam: CM33	Same as above but with only a front-facing camera.	*Kansas, Nebraska, Oklahoma.* Samsara front-facing camera models CM31 and CM33.
ZenduIT	ZenduCAM LITE: Single and dual channel dash cameras	Uses real-time risk detection and GPS tracking technology to track fleets and detect events such as harsh acceleration and deceleration, sharp turns and accidents.	*Nevada.* Forward-facing cameras only on plow trucks. Front and rear cameras on attenuator trucks.

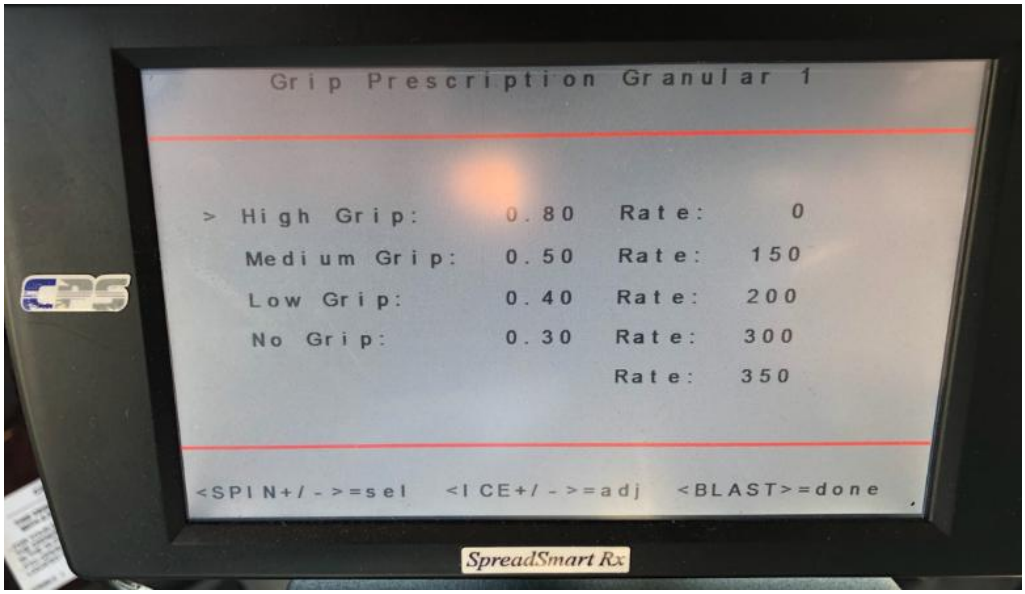

Figure 1. Massachusetts DOT's Previous 7-Inch Display

Figure 2. Massachusetts DOT's Current 10-Inch Display

Camera

The previous equipment was provided with a Panasonic camera. Panasonic spun off their camera group as i-PRO. The camera previously provided, Panasonic WV-S3532LM, is no longer available, and has been replaced by the i-PRO WV-X35302-F2LM. The camera is replacement-compatible with the previous camera. A comparison of the pertinent parameters is shown in the table below.

Parameter	Panasonic WV-S3532LM	i-PRO WV-X35302-F2LM
Image Sensor	Approx. 1/3 type CMOS image Sensor	Approx. 1/2.8 type CMOS image Sensor
Minimum Illumination	Color: 0.03 lx, BW: 0.015 lx	Color: 0.02 lx, BW: 0.02 lx
Dynamic Range	Max 144 dB typ.	144 dB max.
Image Rotation	0°/90°/180°/270°	0°/90°/180°/270°
Focal Length	2.8 mm (1/8 inch)	2.4 mm (3/32 inch)
Angular Field of View	16:9 mode: H: 108°, V: 60° 4:3 mode: H: 89°, V: 66°	16:9 mode: H: 132°, V: 74° 4:3 mode: H: 99°, V: 74°
Network Interface	10BaseT/100Base-TX, M12 connector	10BaseT/100Base-TX, M12 connector
Resolution	16:9 mode: 1920x1080/1280x720/ 640x360/320x180 4:3 mode: 2048x1536/1280x960/ 800x600/640x480/400x300/320x240	16:9 mode: 1920x1080/1280x720/ 640x360/320x180 4:3 mode: 2048x1536/1280x960/ VGA/QVGA
Power	PoE, DV 48V 80 mA, ~3.8W	PoE DC 48V: 180mA, ~8.6W
Ambient Operating Temp.	-40°C to 60°C (Power On range: -20°C to +60°C)	-40°C to 60°C (Power On range: -20°C to +60°C)
Water and Dust Resistance	IP66, Type 4X, NEMA 4X compliant	IP66, Type 4X, NEMA 4X compliant
Dimensions	109mm dia. x 53 mm (H)	109mm (W) x 53mm (H) x 119mm (D)

Figure 3. Details of Connecticut DOT's Dashcam

Material Spreader Controllers

All but one of the responding states currently using AVL/GPS systems also use auxiliary spreader controllers. When using multiple spreader controller models, Tennessee DOT encountered corroded cables and found the maintenance and monitoring of sensitive cables and connections to be unmanageable. Concluding that spreader controllers were not feasible for the agency's fleet, the respondent noted that in-service snowplow dump trucks are covering routes by either plowing or spreading and that data is sufficient for agency needs.

Most respondents identified spreader controller manufacturers but did not indicate models. Alaska DOT&PF is using spreader controllers; Maine DOT is beginning to use them.

Certified Power Solutions and FORCE America were the most common manufacturers cited by respondents. While some agencies identified Certified Cirus products, with Certified Power Solutions' acquisition of Cirus Controls in 2016, responses identifying both vendors are listed under Certified Power Solutions.

Spreader controller manufacturers are identified in Table 9, along with descriptions of the main models as described on the manufacturer's websites and in respondent comments.

Table 9. Material Spreader Controllers

Manufacturer	Product/Model	Description	State and Comments
Bosch Rexroth Canada Corp.	CS 660, CS 630 and CS 620	Three spreader controller models offer solid and liquid applications to optimize material usage while ensuring consistent and accurate delivery rates. • User-friendly interfaces and advanced calibration options. • Seamless integration with hydraulic systems enhance operational efficiency and reduce waste.	*New Jersey.* Model not specified.
Certified Power Solutions	SpreadSmart RX (legacy product)	One of four spreader models, the SpreadSmart is designed with AVL-ready hardware and offers: • Temperature-controlled spreading. • Integrated load and rate management. • Wi-Fi data transfer compatibility.	*Delaware, Iowa, Kansas, Massachusetts, Michigan, Nebraska, Ohio, Oregon* *Nevada.* Sensors indicate whether solid material or prewet brine is active.
Certified Power Solutions	XDS Integrated Plow and Spreader Controls (legacy product)	One of five integrated control models, the XDS is a full-featured advanced spreader control system using CAN-bus technology and includes: • Standard spreader functions and dual spreader (tow plow). • Material positioning spinner control and dynamic gate control used by advanced spreader designs. • Integrated systems with a multifunction joystick; up to four individual joysticks are also available.	*Pennsylvania*
DICKEY-john	Control Point	• Controls granular, liquid material application rates and spinner speed. • Designed to work with a variety of actuators including drop-on actuators (servo valves), pulse-width modulated valves, electric pumps and motorized ball valves.	*Michigan, Minnesota*
Epoke North America	Epomaster X1	Advanced remote control, primarily for the remote control of large salt spreaders.	*Nevada*. Uses with spreader body Epoke SH4900.

Manufacturer	Product/Model	Description	State and Comments
FORCE America, Inc.	SSC6100 Control System	• High resolution 10-inch color LCD. • CAN bus central processing. • Plug-and-play with a single connector to a trailer system, spreader body or other slide in attachments. • Fully integrated with PreCise MRM hardware and antennas for accurate reporting on route, location, material application, accessory details and more. • Available as a standalone spreader controller or integrated within the Patrol Commander Ultra or CommandAll Single joystick consoles.	*Kansas, Minnesota, Nebraska, New Jersey, Ohio, Wyoming* *Connecticut.* Both solid material and liquid are tracked through spreader controller and shared with MDSS and AVL provider for reporting. *Nevada.* SSC6100 CAN Ultra. *Oregon.* Model 6100. *South Dakota*. Models 5100EX and 6100.
Monroe	MPX448 Operator Interface Display (legacy product)	Spreader, prewet, anti-ice and auxiliary/material unload operations.	*Kansas.* A few trucks still have this model.
Muncie Power Products	MESP 3016/3017 and MESP 3020 Electronic Spreader Packages	MESP 3016/3017: • Easy to set up for new or retrofit installations. • Compatible with all spreader bodies. • Group with air, cable or solenoid shift stack valves to control cylinder functions. MESP 3020: Integrated hoist functionality to combine with a hydraulically driven hoist and spreader.	*Ohio, Oklahoma*
Parker Hannifin Corp.	Integrated Spreader Control Systems: IQ-100, IQ-200 and IQ-300	• Compact electronic components for improved cab ergonomics. • Wide range of load sense hydraulic components.	*Nevada*. Model not specified. *Oregon.* Master Controllers - IQAN-MC2, MD3 (legacy products).
PENGWYN	SW Series Spreader Control	• Safe, easy operation with switch or dial on control console. • Optional alarms alert if low material or operational issues.	*Ohio*

Mobile Data Terminals or Computers

Six responding agencies use mobile data terminals or computers in winter maintenance trucks. Connecticut DOT drivers use tablets to enter road conditions and see weather information. Pennsylvania DOT uses AT&T. Four other respondents provided mobile data terminal manufacturers and models, summarized in Table 10.

Table 10. Mobile Data Terminals

Manufacturer	Product/Model	Description	State
Geotab, Inc.	GO9 Advanced GPS Tracking System	• Location tracking and vehicle health assessments. • Collision detection and notification. • In-vehicle driver coaching. • Advanced data capture.	*Minnesota*
OnLogic	Karbon 300: Compact Rugged Computer	• Integrated CAN bus, PoE+ LAN. • Customizable DIO with options for cellular wireless connectivity. • Operates between -25° and 70° Celsius.	*South Dakota*
Parsons Corp.	Mobile Data Collector	• Configured to interface with multiple components on the plow, as well as the vehicle itself. • Collects raw data from the plow, the vehicle, the engine bus and any ancillary weather sensors. • If equipped with a camera, collects a screenshot of road conditions.	*Michigan*
Samsara, Inc.	Vehicle Gateway VG-54	• High-precision, improved GPS with real-time visibility. • Integrated platform works with Samsara wireless sensors, camera modules, Samsara USB accessories and Wi-Fi devices. • High-speed 4G LTE Wi-Fi hotspot.	*Iowa*

Pavement and Weather Sensors

Fourteen respondents use either pavement sensors, weather sensors or both in conjunction with their AVL/GPS systems. Many identified a manufacturer and some identified specific products or models. Responses regarding pavement and weather sensors and additional product information are summarized in Table 11.

Some respondents use pavement sensors (*Connecticut, Maine* and *Ohio*) generally but did not provide specific information. Connecticut and Ohio use air temperature sensors; Connecticut DOT's drivers enter weather observations manually. Other respondents described the use of weather sensors:

- *Maine* uses road weather information system (RWIS) stations to gather weather-related information.
- *Tennessee* uses Geotab's built-in weather radar overlay on its map.
- *Pennsylvania* uses truck manufacturer products from Mack, Ford and other vendors.

Alaska DOT&PF does not use pavement or weather sensors; Oklahoma DOT is exploring weather sensors.

Table 11. Pavement and Weather Sensors

Manufacturer	Product/Model	Description	State and Comments
PreCise MRM, LLC	ARC Air and Road Conditions System	While respondents did not specify a particular model of PreCise sensor, this device appears to be the air and road condition system offered: • Captures humidity, road and air temperatures. • Display shares live readings from the sensor. • Fully compatible with FORCE America controllers and PreCise MRM GPS devices for data collection.	*Nebraska, Oregon, Wyoming* *Minnesota.* Air and pavement sensors. *South Dakota*. Also uses WCM-02 ARC remote in-cab display.
RoadWatch	RoadWatch Sensor Kit	• Measures air and road surface temperatures. • Offers optional display and extension cable.	*Iowa, Oregon, Wyoming* *Michigan*. Weather sensor.* *Nebraska*. Air and pavement temperature sensors. *Nevada*. Temperature sensor.
Vaisala	Mobile Detector MD30	• Measures surface state, grip, layer thicknesses and surface temperature. • Designed for snowplows; suitable for any vehicle. • Can be combined with video and photo data and visualized online.	*Iowa, Nebraska.* Testing MD30 sensors. *Massachusetts.* Uses grip measurements to control spreader output rate.

* Michigan DOT also uses Buyers Products underbody blade sensors and Techon, Inc. wing blade sensors for pavement.

Plow Controllers or Position Sensors:

Eight respondents use plow controllers or position sensors in conjunction with their AVL/GPS systems. The Alaska respondent noted it was possible to connect to the plow "float" system indicator. Oregon DOT uses hydraulic pressure sensors; Pennsylvania DOT is in the process of exploring plow controllers or position sensors.

Tennessee DOT's plow controllers or position sensors required custom-built brackets, and the maintenance and monitoring of sensitive cables and connections was unmanageable. If dump trucks are running, the respondent noted, they are either plowing or spreading, which constitutes route coverage and that knowledge is sufficient for agency needs.

Other respondents identified plow controller manufacturers and products, as summarized in Table 12.

Table 12. Plow Controllers

Manufacturer	Product/Model	Description	State and Comments
Anfield Sensors, Inc.	SMA/SMF High Pressure Switch	• Ideal for many hydraulic and pneumatic applications including material handling equipment. • Proven piston/diaphragm design to provide excellent accuracy and high proof pressures with zero leakage.	*Nevada.* Part #SMA-6-4S-C-FLDR.
AutomationDirect	Micro Detectors Wide Area Sensors	• CX0 and CX2 Series basic area sensors have a sensing distance of up to 6 m and a detection height up to 320 mm and 960 mm, respectively. • Available Teach-in functions with two levels of adjustment are used for product setting, adjustment and blanking.	*Iowa.* Model not indicated.
Certified Power Solutions	Plow Controls	Types of plow controls: • Air and cable controls • Multi-Stix • Uni-Grip • MDC System • EZ-Plow System	*Iowa.* Model not indicated.
FleetPilot by Certified Power Solutions	Plow Controls	• Offers compact, hand-held units for one-ton trucks to advanced proportional systems for multifunction plow vehicles. • Pneumatic, cable-driven or fully electronic plow controls. • Field-proven Mako electronics and ergonomic joystick designs.	*Nebraska.* Model not indicated.
FORCE America, Inc.	Patrol Commander Ultra	• Fully proportional control system with up to five individual joysticks. • Supports multiple float options and switches. • Integrates with FORCE America 5100ex and 6100 spreader controllers.	*Nebraska.* Model not indicated. *South Dakota*: Patrol Commander Ultra. *Wyoming.* Model not indicated.
Muncie Power Products	Omni System Control System Products	Three Omni System models have replaced older systems still listed on website.	*Oklahoma.* Model not indicated; agency also uses a Gems Sensors and Controls oil pressure switch model PS71.

Installation and Operation

Many agencies have not encountered difficulties installing or connecting auxiliary equipment to the AVL/GPS systems (*Iowa, Massachusetts, Michigan, Minnesota, Nebraska, Ohio, Oklahoma, South Dakota, Tennessee* and *Wyoming*).

Pennsylvania DOT's agency mechanics don't always have time to install and maintain auxiliary equipment. Other respondents indicated a variety of issues integrating auxiliary equipment with AVL/GPS systems:

- *Calibrating the plow sensor* can be challenging, particularly in heavy snow conditions when the belly plow sensor does not operate accurately (*Alaska*).
- *Truck cab space* may be insufficient for a large amount of equipment such as controls for multiple plow sets and graphical user interface screen (*Connecticut*).
- *Data transmission cables* need to be the proper type (*Maine*) and length (*Kansas*). Kansas DOT could not run cables from under the dash to back of the cab and now hook up the gateway at the back of the cab.
- *Device updates* necessary for proper integration and functioning included vendor software (*Maine*). Controller firmware such as agency-specific programing for Parker controllers was needed to communicate with the AVL/telematics (*Oregon*).

Similarly, while most responding agencies did not report difficulties with the operational compatibility between auxiliary equipment and AVL/GPS systems, a few respondents noted operational challenges, including two related to vendors:

- Delaware DOT was able to access data from ground speed controllers at no cost until Certified Cirus (Certified Power Solutions) encrypted the system and required additional proprietary hardware to visualize the data.
- Nebraska DOT uses older (at least 10 years) Certified Power Solutions spreader controllers that use adapters to process the streaming data from the controller to third-party AVL providers, which was successful for many years when using Parsons AVL. After switching to Samsara AVL, the vendor ensured the adapters were properly programmed but did not update the firmware in the devices to accept the streaming data. When the agency could not see the spreader controller data, the vendor took several months to rectify the situation.

Respondents identified other operational challenges:

- *Sporadic controllers* can result in misleading data (*Minnesota*).
- *Third-party cameras* used in conjunction with other equipment necessitate navigating two different interfaces, which can be challenging (*Minnesota*).
- *Plow position accuracy* can be difficult with a pressure switch model, which creates uncertainty whether the plow is on or off the truck (*Oregon*).

2.5 Uses and Management of AVL/GPS Data

A range of data is generated by AVL/GPS systems and auxiliary equipment, offering a wide variety of data uses and resulting in several data management issues.

Agency Uses of AVL/GPS Data

Survey respondents' AVL/GPS data uses are described below in three categories:

- Monitoring real-time conditions.
- Real-time operations tracking.
- Planning and operational analysis.

Respondents identified whether their agencies share images or videos on a webpage and/or provide vehicle locations through agency traveler information systems. Additionally, they described management considerations for publicly sharing data. All responses related to data sharing are summarized below in the Data Sharing section.

Note: Tracking and optimizing material usage is a focus for many state DOTs. Responses regarding material usage addresses both real-time operations tracking and planning as well as operational analysis. For example, while Kansas DOT tracks real-time material usage in some trucks, the agency also uses its Samsara AVL units' material data for more operational purposes because not all trucks are similarly equipped.

Monitoring Real-Time Conditions

As summarized in Table 13, over half of the respondents use AVL/GPS systems for monitoring and reporting on temperature. Slightly less than half monitor and report on road conditions. Only two states (*Nebraska* and *Wyoming*) report on humidity values. Related survey responses regarding auxiliary pavement- and weather-sensing equipment are summarized in the section on Pavement and Weather Sensors.

Table 13. Real-Time Condition Monitoring With AVL/GPS Data

State	Humidity	Temperature	Road Condition
Alaska			
Connecticut		√	√
Delaware			
Iowa		√	
Kansas			
Maine		√	√
Massachusetts		√	√
Michigan		√	√
Minnesota		√	√
Nebraska	√	√	
Nevada			
New Jersey			
Ohio		√	√
Oklahoma			√
Oregon		√	
Pennsylvania		√	
South Dakota		√	√
Tennessee		√	√
Vermont			
Wyoming	√		√
Total	**2**	**12**	**10**

Real-Time Operations Tracking

AVL/GPS systems track various real-time operational parameters involving vehicles, equipment and materials. Survey responses identifying six real-time variables DOTs are tracking are identified in Table 14. Additional operational parameters agencies are tracking with AVL/GPS equipment include:

- Asset utilization (*Oregon*).
- Idling time (*Massachusetts* and *Nebraska*).
- Route completion metrics (*Massachusetts*).
- Crash or harsh events and speeding (*Nebraska*).

Table 14. Real-Time Operations Tracking With AVL/GPS Data

State	Vehicle Diagnostics	Plow Status	Vehicle Location or Fleet Monitoring	Time Roadway Plowed and Material Used	Provide Data to a Maintenance Decision Support System	Track and Adjust Material Application Rates
Alaska	√		√	√		
Connecticut	√		√	√	√	√
Delaware	√	√				
Iowa	√		√			
Kansas	√		√			
Maine	√		√	√		
Massachusetts	√		√	√		√
Michigan	√	√	√	√	√	√
Minnesota	√		√		√	√
Nebraska	√		√	√	√	√
Nevada	√	√	√			
New Jersey	√		√	√		
Ohio			√	√		
Oklahoma	√	√	√	√	√	
Oregon	√	√	√			√
Pennsylvania	√		√	√		√
South Dakota		√	√	√	√	√
Tennessee	√	√	√	√	√	
Vermont	√		√	√		
Wyoming			√	√	√	√
Total	**17**	**7**	**19**	**14**	**8**	**9**

Expansion Plans for Operational Tracking

Several state DOTs are interested in reporting on material usage as a future use of AVL/GPS systems (*Maine, New Jersey* and *Wyoming*). Massachusetts DOT described two efforts to enhance material applications with AVL/GPS systems:

- Retrofitting existing SpreadSmart controllers with larger screens and 360° cameras and specifying larger screens on new equipment. Vaisala MD30 mobile RWIS values are displayed on the screen also. “It is so darn impressive,” noted the respondent.
- Working toward implementing a fleetwide program using grip measurement to set the salt spreader rate of material application.

Other planned operational measures that AVL/GPS can support included route reporting (*Maine*), plow status (*New Jersey*) and Driver Vehicle Inspection Reports (*Nevada*).

Planning and Operational Analysis

In addition to supporting operations in real time, state DOTs use AVL/GPS data for longer-term planning and performance evaluation. Respondents reported on their agencies’ use of data for five different purposes as summarized in Table 15. Most respondents use AVL/GPS data for material usage tracking and analysis, followed by analyzing operations after winter weather events.

The Iowa DOT respondent also noted that the agency uses AVL/GPS data for end-of-the-season after-action reviews with district and garage supervisors and in various research projects. AVL/GPS data may also support Oregon DOT’s exploration of vehicle electrification potential through data points such as driving routes, speeds and ambient temperatures to identify optimal charging locations.

Table 15. Planning and Operational Analysis With AVL/GPS Data

State	Route Planning and Optimization	Analyze Operations After Winter Weather Events	Inventory Liquid or Solid Material	Operational Analysis, Evaluation and Performance Reporting	Material Usage Tracking and Analysis
Alaska					√
Connecticut	√	√	√	√	√
Delaware		√		√	√
Iowa		√	√	√	√
Kansas					√
Maine					√
Massachusetts		√	√	√	√
Michigan		√	√	√	√
Minnesota		√			√
Nebraska		√	√	√	√
Nevada					
New Jersey		√			√
Ohio	√	√		√	√
Oklahoma		√		√	√
Oregon		√		√	√
Pennsylvania	√	√		√	√
South Dakota		√	√	√	√
Tennessee	√	√		√	

State	Route Planning and Optimization	Analyze Operations After Winter Weather Events	Inventory Liquid or Solid Material	Operational Analysis, Evaluation and Performance Reporting	Material Usage Tracking and Analysis
Vermont					√
Wyoming	√	√	√	√	√
Total	**5**	**15**	**7**	**13**	**18**

Expansion Plans for Planning and Operational Analysis

Alaska DOT&PF indicated interest in implementing all five uses for planning and operational analysis identified in Table 15. Other states, including Tennessee, reported plans for or interest in using AVL/GPS data for maintenance management system tracking functions, including:

- Driver activities (*Connecticut*).
- Level of service (LOS) determinations (*Maine*).
- Integrating snow and ice data from the AVL system to create work orders that tie labor, equipment and materials together by route (*Minnesota*).
- Mileage tracking, preventive maintenance scheduling and fuel reports (*Pennsylvania*).

Respondents identified additional planning and operational analysis purposes for AVL/GPS data:

- Integration with billing system (*Tennessee*).
- Material tracking (*Nevada*).
- Reporting precision *(Maine).*
- Route optimization (*Nevada* and *Vermont*).

Managing AVL/GPS Data

Respondents' perspectives on data quality and management are presented below in four categories:

- Data accuracy.
- Data management responsibilities, including storage.
- Data collection and transfer.
- Data sharing (private and public).

Data Accuracy

In the context of the AVL/GPS data uses described in the previous sections of this report, several states reported no issues with AVL/GPS data accuracy (*Alaska, Kansas, Maine, Nevada, Oklahoma, Pennsylvania* and *South Dakota*). Other survey respondents identified known issues with AVL/GPS data accuracy, and some indicated sources of inaccuracies and the solutions found.

Six agencies (*Connecticut, Delaware, Iowa, Massachusetts, Michigan* and *Nebraska*) identified AVL/GPS data accuracy issues with material application rates or reporting. A few respondents noted GPS location issues. All survey responses regarding data accuracy are summarized in Table 16.

Table 16. AVL/GPS Data Accuracy Issues

Data Issue	State and Comments
GPS Location	*Minnesota*. While GPS location losses have caused missing data points, the agency worked with Geotab and the issue is mostly resolved. *Tennessee*. The agency experiences "standard GPS drift" in urban areas such that trucks on interstates may appear to be on nearby side streets. *Wyoming*. Inaccurate unit locations and status (active/inactive) can occur if seasonal calibrations and firmware updates are not performed.
Materials Application Rates	*Delaware*. The agency is working with its vendor to correct software issues that cause inaccurate material application rates to be displayed. *Massachusetts*. Application rate inaccuracies appear to resolve when spreader controllers are in automatic (not manual) mode and material totals are cleared between events.
Material Reporting	*Connecticut*. Spreader settings in bypass mode can result in out-of-range reporting rates. *Iowa.* Occasional inaccurate materials data are corrected by filtering out data points with large material usage numbers. *Michigan*. Material reporting inaccuracies are due to improper truck calibration and miscommunication between spreader controllers and automated mobile data collectors. *Nebraska*. Inaccurate reports result from improper processing of material usage data from spreader controllers; the agency is working with its vendor to modify the processing. *Oklahoma*. No accuracy issues; hydraulics must be calibrated correctly to obtain accurate material data.
MDSS Reporting	*Minnesota.* Inconsistencies can occur when transferring data to MDSS reports.

Data Management Responsibilities

Survey respondents reported that the responsibility for storing and managing AVL/GPS system data may fall to the agency, to the vendor or be shared between the two. Responses in each circumstance are described below.

Agency

A variety of agency offices manage AVL/GPS data:

- Internal agency staff and IT services manage data stored on agency servers (*Iowa*).
- Bureau of Maintenance manages data stored by the vendor (*Kansas*).
- Responsibility for data stored on the cloud-based AVL system according to retention policies is shared between Maintenance Operations and Asset Management (*Tennessee*).
- District maintenance technicians are responsible for data management (*Wyoming*).

AVL/GPS data in Maine, while stored by the vendor, is managed by supervisors and fleet mechanics for diagnostics purposes. The Nevada respondent acts as the AVL system administrator, handling day-to-day

issues regarding data that is indefinitely stored in the cloud until purged. Long-term roles for managing data have not yet been identified.

Vendor

Managing AVL/GPS data is the responsibility of AVL providers or vendors in 10 states (*Connecticut, Delaware, Massachusetts, Michigan, Minnesota, New Jersey, Ohio, Oklahoma, Pennsylvania* and *South Dakota*). Most of these agencies also rely on the vendor for data storage (*Connecticut, Delaware, Massachusetts, New Jersey*, *Pennsylvania* and *South Dakota*). A few respondents provided additional comments:

- Data is stored on Michigan DOT's advanced transportation management system, and the vendor is responsible for saving and making the data accessible.
- Data is primarily stored on the AVL system database in Minnesota, though the agency's MDSS site also houses some data.
- A third-party software developer — HBE Systems — manages the data for Oklahoma DOT; images and videos are stored locally for use on public and private websites.
- In South Dakota, in the absence of cell coverage, internal hard drives will store up to 72 hours of data and, with cell service, real-time data is pushed to and stored in the cloud.

Shared Responsibility

In Nebraska and Oregon, the agencies and vendors share AVL/GPS data management responsibilities. Nebraska DOT stores data on both vendor and agency servers through an application programing interface. Oregon DOT stores data in cloud-based storage provided by the vendor using agency servers.

Data Collection and Transfer

A few survey respondents reported issues with transferring data to and from AVL/GPS systems:

- Connecticut DOT commonly receives reports that some system software is not user-friendly and difficult for some supervisors to use.
- Iowa DOT had data transfer issues until the agency established an application programming interface (API) that pulls the Samsara data into the agency's resource management system.
- Oklahoma DOT's API is limited to three trucks per pull, so the agency pulls all 700 trucks every 10 minutes.

Rural Connectivity

Ten states do not experience difficulties with data collection and transfer when operating AVL/GPS systems in rural areas with limited to no cell service (*Connecticut*, *Delaware, Iowa, Kansas, Minnesota, Nebraska, Ohio, Oklahoma, Pennsylvania* and *South Dakota*).

Six other states reported challenges when collecting data in rural areas such as in Wyoming, where the spotty cell coverage is related to terrain and isolated routes. In Michigan, the DOT has identified issues retrieving camera data and operators' completed Driver Vehicle Inspection Reports when cell coverage is limited. In Oregon, some trucks operate over multiple shifts outside of coverage areas and the devices cannot store all data before the truck returns to cell coverage.

Some respondents identified solutions their agencies employ to overcome rural connectivity issues:

- Equip plows in certain areas with Starlink (*Alaska*).
- Store bulk data until cell service is restored, then dump to the platform (*Massachusetts* and *Michigan*).
- Use a custom-built map to provide hourly updates instead of continuous updates to reduce gaps in coverage during a winter event (*Tennessee*).

Data Sharing

The survey queried respondents on how they use images, video and plow location information gathered through their AVL/GPS systems. Delaware DOT shares vehicle location data through its traveler information system and plans to incorporate video or images from a forward-facing cab camera in the future. Similarly, Oregon DOT plans to provide public-facing traffic notifications.

Agencies indicated whether data is shared publicly or privately. Two states share data both privately and publicly. Oklahoma DOT has both public and private websites that serve different purposes. The private Oklahoma DOT website requires log-in credentials and dual authentication.

Video from Wyoming DOT equipment may be streamed to an internal webpage and is typically only used for in-house operational purposes. Still images from plow cameras are shared to a public webpage, and the agency's transportation management center (TMC) can receive still images from the public, but they must be vetted by a TMC operator before posting to the public information systems.

The remaining responses are summarized in two categories: private or public sharing of AVL/GPS images and video.

Private Image and Video Sharing

Five responding agencies only share images and video privately (*Alaska, Connecticut*, *Pennsylvania, South Dakota* and *Tennessee*), though three share plow location data through agency traveler information systems (*Alaska, Connecticut* and *Pennsylvania*). In Alaska, the agency shares plow location to Alaska 511 to generate audio alerts in drive mode, and Connecticut uses plow location to feed HAAS alerts — a cloud-based digital system for warning drivers of active incidents and hazards to add to safety of operations and MDSS supply of information.

Public Image and Video Sharing

Kansas DOT was the only state planning to publicly share video from plow trucks. The agency will share both video and location through its traveler information system — KanDrive — starting next season. Five other agencies described public sharing of images, including Iowa DOT's sharing of forward-facing camera images on the agency's 511ia page.

Ohio DOT's public information officers provide images and other information from AVL/GPS systems on public-facing websites. Three other states maintain criteria for plow locations and images to appear in the agencies' traveler information systems:

- In Michigan, a plow truck must be traveling at least 10 mph, be located at least a mile from its maintenance facility, and be plowing or spreading for front camera images to appear on MiDrive.

- Still images from plows will be visible on Minnesota DOT's 511MN site when trucks are traveling at least 10 mph on a state highway.
- Nebraska 511 shows plow trucks on state-maintained routes. Trucks appear as icons that, when clicked, identify the truck location over the past two to three hours and display the current windshield camera still image.

2.6 Agencies Interested in AVL/GPS Systems

Neither Louisiana DOTD nor West Virginia DOT currently use AVL/GPS systems. Louisiana has limited winter maintenance needs due to its climate and does not own snowplows, but the agency is interested in using AVL/GPS technologies as the state advances its winter response capabilities in the future.

West Virginia DOT had AVL/GPS on some vehicles about 20 years ago, but the units were disabled around 2019 at the request of management. Currently, the agency is actively investigating AVL/GPS potential with current management support, and West Virginia DOT's implementation of AVL/GPS could happen soon.

Each respondent identified the potential uses of AVL/GPS capabilities to gather data for winter maintenance operations, as summarized in Table 17.

Table 17. Interested Agencies' Potential AVL/GPS Data Uses

Potential AVL/GPS System Use	Louisiana DOTD	West Virginia DOT
Collection of vehicle diagnostic data		
Humidity reporting		√
Material usage tracking and analysis	√	√
Road condition reporting	√	√
Route planning and optimization	√	√
Sharing of images or video on web page		√
Sharing of vehicle location through agency traveler information system		√
Temperature reporting		√
Vehicle location tracking or fleet monitoring	√	√

2.7 Assessing AVL/GPS Systems

In assessing the use of AVL/GPS systems in winter maintenance operations, respondents identified the greatest benefits of using these systems as well as the primary challenges. Survey responses are summarized below, followed by lessons respondents have learned through using AVL/GPS systems and auxiliary equipment that can help inform other agencies exploring the potential of AVL/GPS systems to enhance winter maintenance operations.

Benefits

Respondents identified a range of benefits associated with the use of AVL/GPS systems to manage winter maintenance. Enhancing operations management, monitoring real-time conditions and providing

public traveler information were commonly identified; respondents also mentioned material tracking, recording crashes and other incidents, and vehicle diagnostics. Survey responses are summarized in Table 18.

> When managing winter operations, you can't manage it if you don't measure it.
>
> — *Iowa DOT respondent*

Table 18. Benefits of AVL/GPS System Use

Benefit	State and Comments
Employee Safety	*Kansas, Tennessee.* Allows for the location of vehicles for employee safety. *Oregon*. Reduces unsafe driving behaviors and allows for the location of employees working alone or in remote areas.
Incident Recording	*Iowa*. Reduces claims when using forward- and rear-facing video cameras. The video tells the story of an incident and who was at fault. Iowa State Patrol has also used the video data to issue citations. *Nevada, Oregon*. Provides data to support operators in the event of a legal claim. *Oklahoma, Pennsylvania, Tennessee*. Produces good records to respond to crashes.
Material Tracking	*Connecticut, Kansas, Pennsylvania, South Dakota* *Massachusetts, Michigan*. Identifies where, when and how much deicing material has been applied. *Minnesota*. Reports material usage to MDSS to create end-of-shift reports.
Monitoring Real-Time Conditions	*Connecticut.* Allows for monitoring of weather and severity. *Massachusetts.* Provides equipment location. *Michigan*. Assists with snowplow operations: • Location tracking • Plow blades up or down • Truck speeds *Nevada.* Provides vehicle location in the event of a mechanical failure. *Pennsylvania.* Provides vehicle location for snow removal operations. *South Dakota.* Provides dashcam images in 30 seconds. *Tennessee*. Monitors conditions and roadways from strategically placed trucks with 24/7 cameras. *Wyoming.* Provides: • Maintenance fleet location to respond to road hazards, emergencies and road closures. • Status checks on plow drivers. • Location information that can be shared among operators logged into tablets. • Accurate road condition reporting.

Benefit	State and Comments
Operations Management	*Connecticut*. Provides statewide operational awareness of conditions. *Delaware*. Provides data for developing a plow/route completion map. *Iowa, Pennsylvania*. Assists with managing winter operations. *Massachusetts*. Manages plow routes given route status, precipitation rate and equipment location. *Michigan*. Uses camera images to ground truth MDSS. *Nebraska*. Tracks location and responses to road weather conditions; supports operational management and training of operators. *Oklahoma.* Tracks truck routes and ensures roads were cleared. *Oregon*. Manages and analyzes material applications. *South Dakota*. Achieves LOS goals by tracking operations in real-time.
Providing Public Traveler Information	*Alaska*. Provides plow locations via Alaska 511, including "maintenance vehicle ahead" audio alerts in drive mode application. *Connecticut.* Includes third-party navigation warning using HAAS alerts. *Iowa*. Provides near real-time truck location and webcam images of plowing locations for the traveling public on agency's 511ia page. *Minnesota.* Creates *i*mages appearing on 511MN. *Nebraska.* Increases public awareness of winter weather response and current road conditions. *Oklahoma.* Allows for public and private viewing of road conditions. *Tennessee.* Offers real-time data for: • Route coverage. • Number of trucks running. • Miles driven. • Hours worked.
Responding to Complaints	*Delaware.* Generates data that supports agency response to complaints. Pennsylvania. Helps respond to reports of unplowed areas.
Vehicle Diagnostics	*Alaska.* Produces engine codes that state equipment fleet staff can see and immediately receive tailored alerts. *Delaware, Minnesota* *Michigan.* Completes Driver Vehicle Inspection Reports through the system. *Nebraska.* Generates vehicle diagnostic codes that support response to malfunctions, reducing preventable failures and cost of major repairs.

Challenges

Agency respondents described a range of challenges encountered when using AVL/GPS systems in winter maintenance operations. Tennessee DOT struggles with transparency, noting that data is not public-facing but is pulled and released to the public, similar to other states' public-facing route coverage maps. Finding the balance of how much information to provide and maintaining a website, the respondent said, is challenging. Oregon DOT reported concerns with creating reports from AVL/GPS data.

Most survey responses regarding challenges in using AVL/GPS data summarized below, fell into one of three categories:

- Acceptance or buy-in of AVL/GPS systems by the workforce, management and others (nine agencies).
- Data integrity and accuracy (eight agencies).
- Operation and maintenance issues (10 agencies).

Acceptance or Buy-In

Several respondents noted that operator, crew or workforce acceptance of AVL/GPS equipment has been problematic (*Alaska, Connecticut, Massachusetts, Oregon, Pennsylvania, South Dakota* and *Wyoming*). Pennsylvania DOT does not use the AVL/GPS system as a disciplinary tool, with the respondent commenting, "Trust in the operators, the operators don't want big brother watching so they tamper with items." Similarly, Wyoming DOT seeks to have employees understand the intent in using the system is not to watch them, but to increase safety and efficiency for both operators and the public. Michigan DOT strives to obtain statewide buy-in and understanding that the system is there to be helpful.

Responding agencies identified other stakeholders who may be slow to embrace the capabilities of AVL/GPS technologies and the return on investment offered by these tools:

- Employees' union (*Connecticut*).
- Management (*Iowa*).
- Vendors (*Massachusetts*).

Data Integrity and Accuracy

Some survey respondents described issues or uncertainty with AVL/GPS data and other equipment output. General comments included data integrity (*Minnesota*), incomplete or inaccurate data (*Nebraska*) and whether or not the measurements are inverted, such as strobe lights on or off, and plows up or down (*Nevada*).

More specific challenges with accuracy of AVL/GPS outputs included:

- Plow position sensing (*Alaska* and *Oregon*).
- Material data (*Michigan* and *Pennsylvania*). The Pennsylvania DOT respondent questioned material accuracy, wondering about the possibility of a spreader "just spreading air."
- Seat belt notifications when the truck is already moving are not recognized by the system in heavy-duty trucks (*Kansas*).

Operation and Maintenance

The operation and maintenance challenges with AVL/GPS systems experienced by responding agencies are summarized in Table 19. Issues related to installing and maintaining systems were most commonly reported, followed by systems going offline for reasons such as a gap in cell coverage.

The Nevada DOT respondent provided additional context for the agency's challenges, highlighting the continued navigation of hardware-related aspects of implementation in an effort to generate consistent and reliable data. While winter operations data is being generated, the agency is "not using it in any

productive way at this time." As the respondent noted, "With approximately 14% of AVL/GPS devices offline at any given time, it is difficult to be 100% confident in the data and reporting."

Table 19. Operation and Maintenance Challenges With AVL/GPS Data

Challenge	State and Comments
Calibration of Material Tracking	*Alaska, Wyoming*
Cost Concerns	*Connecticut*. Cost and funding. *Tennessee*. The cost to develop a driver-facing GPS system showing route information is not feasible given the lack of existing available systems.
Installation and Maintenance	*Connecticut*. Keeping the operational tracking and keeping systems in working order. *Delaware*. Ensuring the onboarding process of the new system is done correctly and efficiently to avoid future difficulties. *Iowa*. Although the system requires minimal repairs, the technology can still be challenging at times. *Michigan*. Maintaining the equipment statewide with limited staff. *Minnesota*. Integrating with other sources, such as sensors, MDSS and 511 system.
Physical Connections	*South Dakota*. Truck vibrations cause loose connections. *Tennessee*. Material monitoring cables and connections corrode or break, and repair and maintenance is not worth the data. A wireless solution would be ideal but has not yet been found.
Systems Offline	*Nevada*. If an incident occurs when the system is offline there will be no supporting data. *South Dakota*. Cellular coverage in remote areas can be limited. *Wyoming*. Systems do not perform as intended if tablets are turned off or are out of cell range.
Vendor Concerns	*Delaware:* • Every software and AVL vendor does things differently and learning new systems is time-consuming. • Need to separate what the vendor can actually provide versus what was promised.

Lessons Learned and Best Practices

Responding agencies offered lessons learned and best practices for others using AVL/GPS systems for winter maintenance purposes, as summarized in Table 20. Seven agencies offered suggestions related to AVL/GPS system management, such identifying a product champion (*Delaware*) and prioritizing data to collect and establishing standards and policies prior to implementation (*Oregon*). Gaining acceptance by operators, others in the agencies and the public was also mentioned by several states (*Iowa, Michigan* and *Minnesota*). In Alaska, use of AVL/GPS systems is still new and the agency continues its implementation phase.

Table 20. AVL/GPS Lessons Learned and Best Practices

Topic	State and Comments
Gaining Acceptance	*Iowa:* • Develop a driver safety program and associated policies before installing operator-facing cameras to encourage acceptance by garage staff and district leadership. • Provide winter operations information to the traveling public to establish and maintain credibility. *Michigan*. Produce Driver Vehicle Inspection Reports on AVL tablets. This activity has generated a higher interest in using the AVL system and MDSS. *Minnesota:* • Maintain transparency at all agency levels, including providing expectations, uses and benefits of the system, to build justification for investing in the technology. • Proactively integrate data for downstream consumers.
Fleet Procurement	*Alaska*. Work with maintenance and state equipment fleet managers to inventory equipment. This effort allows an agency to: • Prioritize equipment at stations and camps. • Provide vehicle specifics to vendors for scoping and procurement as the on-board diagnostic cabling can vary by vehicle make, model and year.
AVL/GPS System Management	*Connecticut*. Identify strategies to verify the status and ensure health of entire system to make sure all equipment is functioning correctly. While the agency's system has been useful, sometimes many trucks are not reporting into the system, which is monitored centrally. *Delaware*. Assign a product champion to support effective AVL/GPS system use. *Nebraska:* • Launch pilot studies that can help determine best AVL uses for agency. • Ensure vendors can do what they claim they can. *Oregon*. • Prioritize the data to collect. • Determine how to report data. • Develop agencywide standards and policies prior to AVL/GPS implementation. *South Dakota*. Use AVL/GPS data to inform an agency's LOS. To address South Dakota DOT's practice of "over-achieving" its established LOS, AVL/GPS data has been used for a project to optimize routes and recommend appropriate LOS changes. *Tennessee*. Understand that advertised solutions may not be practical or cost effective for a large fleet. *Wyoming*. Use caution to ensure that AVL/GPS images are accurate and up to date.
Equipment Installation and Maintenance	*Maine.* Troubleshoot problems and use the correct cables to hook up equipment. *Massachusetts*. Install equipment in not-easily-reached areas, such as under the dashboard. *Michigan*. Understand the best location of the AVL equipment in the cab for the operators. *Oklahoma:* • Assign dedicated staff to perform statewide equipment installations. • Ensure multiple people are reviewing images and videos. *Pennsylvania.* Consider including a contractual provision to install the AVL/GPS to specification when trucks are being built. *Wyoming.* Calibrate AVL and spreaders to track winter maintenance material usages.

Topic	State and Comments
Beneficial Data Uses	*Iowa:* • Gather and use material data to support the production of annual post-winter and after-action reports. These reports help garages manage material usage. • Incorporate video into operations to save the cost of potential claims. • Use the Samsara website to aid supervisors in managing resources before and during a winter storm, including deciding when and how to pretreat. *Nebraska*. Consider using an application programming interface to create reports and dashboards. *Wyoming*. Use camera images to inform the public of actual road conditions.

3 Examining the Literature

A literature search examined in-process and published research and other resources that address AVL/GPS technologies used by state DOTs for winter maintenance. Results of the literature search are presented below in five categories:

- Previous Clear Roads Research
- National Research and Guidance
- State Research and Resources
- Vendors and Manufacturers

3.1 Previous Clear Roads Research

Over the past 10 years, Clear Roads' examination of the use of AVL/GPS in winter maintenance has included wide-ranging uses of these technologies and more targeted applications, including how AVL/GPS can inform optimization of snowplow routes and establishment of plow cycle times.

Calculating Plow Cycle Times From Automatic Vehicle Location Data, Ming-Shiun Lee, Mallory Crow and Laura Aguilera Martin, Clear Roads Pooled Fund Study, Minnesota Department of Transportation, February 2024.
https://www.clearroads.org/download/final-report-58/?tmstv=1742926737
From the abstract: Winter weather events can yield low visibility and/or lower the coefficient of friction on the road surface resulting in vehicular crashes or congestion. Transportation agencies are tasked with maintaining safe and reliable roadways for the traveling public which includes combating these snow and ice events. The traveling public's demand for a high level of service (LOS) on roadways continues to increase, even during winter events when significant impacts on travel may occur. It is essential to consider plow and treatment cycle times as agencies work to improve LOS, travel safety, and reliability during snow and ice events. Cycle times can vary significantly depending on a variety of factors, including road type, lane miles, weather, road conditions, traffic volume and more.

This report develops a methodology for calculating plow cycle times that considers various factors that impact cycle times. The methodology was then used to create a framework for a visualization tool that agencies could format with their own electronic data to make real-time operational decisions and conduct better-informed post storm analyses. By developing a visualization tool based on the methodology, agencies will have the ability to track snowplows in real time and make operational adjustments as needed to maximize efficiency. Additionally, agencies will have greater insight for post-storm analyses, performance evaluations, route optimization strategies and resource allocation efforts while leveraging data they likely already collect during the course of their routine winter maintenance activities.

Utilization of AVL/GPS Technology: Case Studies, Ming-Shiun Lee and Dan Nelson, Clear Roads Pooled Fund Study, Minnesota Department of Transportation, June 2018.
https://www.clearroads.org/download/final-report-43/?tmstv=1777997868
From the abstract: This report summarizes the information gathered during the study conducted for the Clear Roads project entitled *Utilization of AVL/GPS Technology: Case Studies*. The research team surveyed multiple state DOTs on the current state of AVL/GPS system usage for the purpose of gathering information on the planning, processes, steps and results observed by agencies with their respective systems. Six state DOTs (Utah, Washington State, Michigan, Wisconsin, Nebraska and Colorado) were selected to conduct detailed case studies. The case studies were performed through in-person

interviews with multiple levels of DOT staff involved in AVL/GPS system planning, procurement, implementation, management and operations. This final report summarizes the key results, findings and lessons learned from the case studies. It also identifies best practices and provides a series of recommendations for winter maintenance agencies to consider in the procurement, deployment and integration of an AVL/GPS system for winter maintenance operations.

Identifying Best Practices for Snowplow Route Optimization, Jonathan Dowds, James Sullivan, David Novak and Darren Scott, Clear Roads Pooled Fund Study, Minnesota Department of Transportation, December 2016.
https://www.clearroads.org/download/final-report-24/?tmstv=1777998263
From the abstract: Well-designed winter maintenance routes result in snow and ice control service that is both more effective, because roads are cleared more rapidly, and more cost-efficient, because deadheading, route overlap and other inefficiencies are reduced or eliminated. There are an increasing number of computerized tools to facilitate the routing process, but these tools are not yet widely used by winter maintenance practitioners. The purpose of this report is to provide practitioners with an overview of computerized route optimization processes and concrete recommendations about how to ensure that route improvement efforts produce actionable results. Recommendations are synthesized from nine recent and ongoing snowplow routing projects using a variety of computerized routing tools. Project descriptions, based on interviews with project personnel, focus on project goals, optimization software features used and lessons learned. Multiple route optimization projects report route length reductions on the order of 5% to 10%, with reductions as high as 50% reported in one case. These snowplow route optimization projects show that route optimization is a powerful tool for improving routing efficiency but that it does not replace the need for expert judgment in the route design process. Successful route optimization projects rely on close cooperation between experienced winter maintenance professionals and the individuals conducting the route optimization as well as a highly accurate, snowplow--routing specific representation of the road network. Successful projects also include time to review and revise new routes to identify potential problem spots prior to implementation.

Synthesis on Global Positioning Systems/Automatic Vehicle Location Equipment Used for Winter Maintenance, Adrian Potter, Mark Gallagher and Clayton Bayer, Clear Roads Pooled Fund Study, Minnesota Department of Transportation, July 2016.
Publication available at http://clearroads.org/project/synthesis-on-gpsavl-equipment-used-for-winter-maintenance/
From the abstract: This project gathered information about available Global Positioning Systems/Automatic Vehicle Location (GPS/AVL) equipment and vendors to gain an understanding of their use by state and local agencies for winter maintenance activities. Depending on the complexity desired, many tools and equipment can comprise these systems, including truck controllers, data collection devices, communication devices, plow sensors and software. This equipment allows agencies to better manage and analyze their winter maintenance operations. There are also numerous choices agencies have in what GPS/AVL solutions to employ, as well as how to effectively use them.

The project included four main tasks: conducting a national search of available literature about winter maintenance GPS/AVL solutions, equipment and technology, developing a survey for state and local agencies to collect data on their experiences with GPS/AVL systems, developing an equipment guide about GPS/AVL equipment based on the literature search and survey results, and developing a synthesis of policies focused on issues and considerations relating to the implementation of GPS/AVL technology for winter maintenance.

3.2 National Research and Guidance

NCHRP Research Report 1119: Automated Applications for Infrastructure Owner-Operator Fleets, Shauna Hallmark, Maroa Mumtarin, Omar Smadi and Theresa Litteral, 2024.
https://www.nationalacademies.org/read/27903/chapter/1
From the foreword: NCHRP Research Report 1119 provides the current status of and barriers to the implementation and application of autonomous vehicles (AV) and other automated technologies that may potentially supplement or replace infrastructure owner-operator (IOO) fleets. Autonomous or automated technologies may reduce the risk of worker injury and ease workforce shortfalls in state departments of transportation (DOTs) and other IOOs. This report will be of interest to those seeking alternative ways to accomplish tasks that may pose a safety risk to workers, IOOs, those interested in the use of automated technologies in transportation, and those responsible for allocating transportation resources.

From Chapter 8: Automation-Assisted Snowplows: Several different types of automation have been utilized for snowplows, with automatic vehicle location/locating (AVL) as the primary automated function. GPS technology is used to track snowplows' progress, which can be used to optimize route efficiency. Agencies are able to monitor sensor data and adjust to changing conditions in real time. The technology can also be used to provide an operator's view of the roadway and inform the public about the location of snowplows. Other types of automated functions for snowplows have included additional communications capacity, such as wireless or on-board units (OBUs).

Note*:* Brief examples included in this chapter describe how eight state DOTs have implemented automation-assisted snowplows to support winter maintenance operations. These states include Colorado, Michigan, Nebraska, Nevada, Ohio, Utah, Washington and Wisconsin.

3.3 State Research and Resources

The state research and other resources below describe the use of AVL/GPS for snowplow location, weather conditions, camera interfaces and snowplow driver assistance.

Multiple States

"Controlling the Spread," Paul Mortell, *Roads & Bridges*, August 29, 2016.
https://www.roadsbridges.com/controlling-spread
This article describes automated spreader control systems used by Massachusetts DOT, the town of Penfield, New York, the city of South Burlington, Vermont, and Maine DOT. Topics covered include system components, salt use and increasing efficiencies, benefits of automating systems and analysis of results.

Indiana

"Automatic Vehicle Location is Our Newest Tool for Winter Operations," Indiana Department of Transportation, *Inside InDOT*, January 2021.
https://www.in.gov/indot/div/newsletters/January2021/AVL-F.pdf?utm_medium=email&utm_source=govdelivery
From the article: INDOT [Indiana DOT] is leading the charge nationally with automatic vehicle location (AVL), in which our plow trucks automatically transmit their geographic location and data to INDOT Winter Operations managers. All 1,100 of INDOT's plow trucks have been equipped with AVL. Installation was completed in five districts by December…

Iowa

"Iowa DOT's Mobile Truck Cameras and GPS Experience," Tina Greenfield and David May, Iowa Department of Transportation, *Equipment Management Technical State Partnership National Conference*, June 2016.
https://pavementvideo.s3.amazonaws.com/2016_EMTSP_National/PDF/16_Iowa%20DOTs%20Mobile%20Truck%20Cameras%20and%20GPS%20Experience_May.pdf
This presentation describes Iowa DOT's "plow data story" including:

- Initial GPS/AVL development
- Dash cameras
- Involving the public
- Future direction
- Lessons learned

Minnesota

Using AVL/GPS Telematics to Optimize Snowplowing, Minnesota Local Road Research Board, January 2024.
https://hdl.handle.net/20.500.14153/mndot.16124
From the document: Several agencies have deployed AVL systems with varying levels of data collection. Costs vary depending on data points collected, frequency of data collection and level of analysis desired by the users. Minnesota's local agencies reported $20-$30 per month per unit as typical fees. Some systems like Motorola StreetTrek or TRBOnet Enterprise utilize existing Motorola two-way radio systems eliminating monthly per unit fees. A system can be deployed for $1,200 per year.

Related Resource:

> **Using AVL/GPS Telematics to Optimize Snowplowing**, Video, Local Road Research Board, 2024.
> https://www.youtube.com/watch?v=rW4I6zoWqTM
> *From the video description*: Increasingly, local agencies are using new technologies to improve operations. Several Minnesota agencies deployed AVL/GPS Telematics, which enables them to track data in order to optimize snow removal. Find out what they learned. Produced by the Minnesota Local Road Research Board. Visit us on the web at http://www.lrrb.org.

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/_flysystem/fedora/2023-06/202327.pdf
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.

Pennsylvania

Snowplow Cameras and Automated Vehicle Locator Innovation, Pennsylvania State Transportation Innovation Council, Pennsylvania Department of Transportation, undated.
https://www.pa.gov/content/dam/copapwp-pagov/en/penndot/images/about-us/statetransportationinnovationcouncil/innovations/publishingimages/snow-plow-cameras-and-avl/snow%20plow%20camera%20and%20avl%20lessons%20learned.pdf
From the overview:

> The purpose of the snowplow cameras is to capture real-time video and static images of the roadway in front of and behind plow trucks during winter operations. By integrating the cameras with PennDOT's [Pennsylvania DOT's] existing Automated Vehicle Locator (AVL) system, the location and movement of every plow truck is tracked.
>
> Integrating cameras, which work with the existing Geotab AVL installed in the trucks, enhances the system to provide maintenance and traffic management personnel with better situational awareness of actual road conditions during winter weather events. Video can be requested live through the system, or up to 40 hours of prior video can be requested from the digital video recorder (DVR) mounted in the truck.

In addition to providing cost information, this document describes challenges overcome in the following topic areas:

- Union discussions
- Navigating the procurement process
- Ordering the right equipment
- Platform modifications
- Rear cameras lost visibility from salt residue
- Traffic management center and eventual 511PA integration

Texas

"A Multi-Purpose All-in-One Mobile Data Collection System for Snowplow Operation Management," Pooya Darghiasi, Anil Baral, Bahram Abediniangerabi and Mohsen Shahandashti, *International Conference on Transportation and Development*, August 2022.
Citation at https://ascelibrary.org/doi/10.1061/9780784484326.005
From the abstract: The objective of this research is to develop a multi-purpose all-in-one mobile data collection system for snowplow fleet to communicate road condition images along with snowplow locations during winter operation. In this research, a cellular Android tablet with an embedded camera and GPS device is programmed and installed in snowplows to automatically collect and transfer geotagged road condition images at predetermined time intervals (e.g., 10 min) when the snowplow is moving at the speed of 5 mph or more. Moreover, a web-map ArcGIS interface is developed to visualize the collected road condition images and snowplow locations along with weather-related information provided by national weather services (e.g., current ambient temperatures, snowfall forecast, and issued watches, warnings and advisories). The developed system was implemented in the TxDOT [Texas

Department of Transportation] Wichita Falls District on five (5) snowplows for the 2020–21 winter season. The system captured the historic winter storm in Texas in February 2021. The results, including more than 120 geotagged road condition images visualized on the web-map interface, provided helpful information for transportation operation managers to better oversee the real-time road condition and make well-informed decisions during snowplow operation. The developed system is expected to facilitate equipping the snowplow fleet with a mobile data collection system to communicate adverse road conditions, improve snowplow operational decisions and consequently decrease weather-related crashes on roadways.

3.4 Vendors and Manufacturers

Websites for the vendors and manufacturers offering the AVL/GPS and auxiliary equipment referenced in this synthesis report are provided below along with the *noted products* used by a responding agency.

Anfield Sensors, Inc., 2026.
https://anfieldsensors.com/
From the website: Anfield Sensors Inc. is a leading manufacturer of hydraulic and pneumatic sensors, specializing in pressure, vacuum, differential and temperature switches/transducers.

Noted product: SMA/SMF High Pressure Switch

AutomationDirect, 2026.
https://www.automationdirect.com/adc/home/home
From the website: We've shopped the U.S. and around the world to bring you the most practical, reliable industrial control products at the best prices. And we always list current pricing and availability on our webstore, so you know exactly what's available and the cost without being forced to contact us.

Noted product: Micro Detectors Wide Area Sensors

Bosch Rexroth Canada Corp., 2026.
https://www.boschrexroth.com/en/ca/
From the website: Using electrified, electronic and digitally networked solutions, we are helping you to create the next generation of mobile machines. Our performance gives you access to increased power, safety, efficiency and intelligence.

Noted products: Technical Documents: Electronic and Hydraulic System Solutions for the Snow and Ice Industry:

- CS 660 (integrated spreader controller)
- CS 630 (solid and liquid controller)
- CS 620 (solid controller)

Caterpillar, 2026.
https://www.cat.com/en_US/by-industry/construction-industry-resources/technology/visionlink.html
From the website:

Equipment Management Software That Gives You The Inside Story
Do you really know what's going on with your equipment and jobsites? No matter what size your fleet may be, VisionLink tells you what you need to know. It eliminates guesswork so you can take informed action. An updated interface helps you improve fuel efficiency, reduce idle time and boost profitability across all your assets. VisionLink puts the power of knowing in your hands.

Noted product: VisionLink: The Power of Knowing, fleet management software to provide real-time data on location, fuel and truck maintenance variables.

Certified Power Solutions, 2026.
https://www.certifiedpower.com/
From the website: Certified Power Solutions is a leading provider of engineered hydraulic and electronic systems for mobile and industrial markets across North America. Since 1967, we have partnered with OEMs [original equipment manufacturers] to design, manufacture, distribute and support integrated solutions that improve equipment performance, reliability and efficiency.

Noted products:

- SpreadSmart RX (legacy product)
- XDS Integrated Plow & Spreader Controls (legacy product)
- Plow Controls (includes air and cable controls, Multi-Stix, Uni-Grip, MDC System and EZ-Plow System)

Dakota Micro, Inc., 2026.
https://dakotamicro.com/
From the website: Dakota Micro backup camera systems set the industry standard with its premium camera systems tailored for both equipment and vehicles. Crafted with precision engineering, our products are designed to deliver unparalleled quality and performance. From construction sites to agricultural fields and RV road trips, our cameras provide a clear view of your environment.

Noted product: EnduraCam CVBS 92° NTSC Camera (DMEC-LC)

DICKEY-john: A Division of TSI, 2026.
https://dickey-john.com/
From the website: Whether you're a public works vehicle manufacturer or a dealer, you want to equip your maintenance vehicles to deliver reliable performance for the communities that rely on them. Turn to DICKEY-john for the most advanced speed sensors, control systems, valves, flow meters and other accessories designed to optimize salt and sand spreading, plow control and more.

Noted product: Control Point (spreader controller)

Epoke North America, 2025.
https://epokena.com/
This Canadian company offers bulk, liquid and towed spreaders. The noted product below is "Epoke's advanced remote control, primarily for the remote control of large salt spreaders."

Noted product: Epomaster X1 (spreader controller)

FORCE America, Inc., 2026.
https://forceamerica.com/
From the website: At FORCE America, we are leaders in the fluid power and hydraulic systems industry, dedicated to providing innovative solutions that enhance performance and efficiency for our customers. With over 65 years of experience, we specialize in delivering high-quality hydraulic components, systems and services that meet the evolving needs of various markets, including construction, agriculture and industrial applications.

Noted products:

- SSC6100 CAN Bus Spreader Control System (see also page 6 of Municipal Products brochure)
- Patrol Commander Ultra (plow control)

Geotab, Inc., 2026.
https://www.geotab.com/
From the website: Leader in connected fleet management:

- Predictive insights for proactive decision-making: predicts risk before incidents happen.
- Platform and flexibility with virtually no limits: connect the tools you already use, and the ones you'll need down the road.
- Trusted by highly security-conscious organizations: FedRAMP authorized, ISO-27001 certified and compliant with FIPS 140-3 encryption.

Noted products:

- GO Focus AI Forward-Facing Dash Cam
- GO Focus Plus AI Dash Cam
- GO Focus Pro Dash Cam
- GO9 Rugged (asset tracking for harsh conditions)
- GO9+ (asset tracking plus Wi-Fi hotspot)
- GO Anywhere Plus (asset tracking)
- Small asset tracking (Bluetooth beacons)

i-PRO Co., Ltd., undated.
https://i-pro.com/products_and_solutions/en/surveillance
From the website: Through responsible innovation and AI-powered analytics, i-PRO transforms video data into precise, actionable insights — enhancing operational efficiency and enabling businesses to act proactively.

Noted product: All-in-one compact dome camera with AI engine and IR-LED

John Deere & Company, 2026.
https://shop.deere.com/us

Noted product: JD Link Telematics Equipment

Microseven Systems LLC, 2026.
https://www.microseven.com/index.html
From the website: Headquartered in Michigan, United States, Microseven builds high-performance IP camera hardware combined with open firmware and self-hosted real-time infrastructure. The platform enables direct browser-based video streaming using native WebRTC technology and supports flexible integration through open HTTP and CGI APIs.

Noted product: M7D77-POE 1080p IP PoE Wide-Angle Camera (150°)

Muncie Power Products, Inc., 2026.
https://www.munciepower.com/
From the website: Although known for our robust line of power take-offs, Muncie Power is also a provider of hydraulic components for the work truck industry and a variety of other hydraulic applications. As a member of the Interpump Group, Muncie Power has the ability to provide nearly every major component in a hydraulic system with the quality and reliability our customers have come to depend on.

Noted products:

- MESP 3016/3017
- MESP 3020 Electronic Spreader System

MS Foster & Associates, Inc., 2024.
https://msfoster.com/
From the website: MS Foster & Associates, Inc. offers a variety of products to help make your operations run smoother and safer. Whether you are in the automotive, municipal, RV, agricultural, or heavy duty truck markets, you will find our products can help increase safety, reduce accidents and in many cases reduce overall operating expenses.

Noted product: Voyager Vehicle Camera System

OnLogic, 2026.
https://www.onlogic.com/
From the website: Engineered for AI and built for every part of the edge. From industrial automation to real-time AI inference, our hardware is designed to handle your most complex workloads, even in challenging environments.

Noted product: Karbon 300: Compact Rugged Computer

Parker Hannifin Corp., 2026.
https://www.parker.com/ae/en/solutions/electrification/iqan-electronic-control-system.html
From the website: Parker is the global leader in motion and control technologies, providing precision-engineered solutions for a wide variety of mobile, industrial and aerospace markets.

Noted products: Parker Iqan Integrated Spreader Control Systems: IQ-100, IQ-200 and IQ-300

Parsons Corp., 2026.
https://www.parsons.com/
From the website: Monitor your fleet in real-time with mobile data collection and tracking solutions. Gather raw data on location, equipment performance, weather conditions and more, and convert that data into easy-to-understand, actionable information that makes it easier to manage and maintain your equipment.

Noted products: Parsons Mobile Data Collector:

- Data collectors, central system and in-cab display
- MDC-004
- Snowplow monitor (MDC-006)
- Equipment tracker (MDC-007)
- Vehicle tracking camera (MDC-007C)

PENGWYN, 2020.
https://www.pengwyn.com/
From the website: PENGWYN was incorporated in 1987 on the basis of designing and producing a rugged, reliable central hydraulic system to support the needs of snow and ice trucks. In the 25 years since, a complete line of winter highway maintenance products have been designed making PENGWYN the leader in snow and ice highway equipment.

Noted product: SW Series Spreader Control

PreCise MRM, LLC, 2026.
https://precisemrm.com/
From the website: PreCise MRM collects the information you need — from location and speed to the activity of your vehicles' accessories to additional detailed data vital to your day-to-day business. And we deliver that data in a manner that supports your schedule. **Note**: FORCE America, Inc. acquired PreCise MRM in 2009.

Noted product: ARC Air and Road Conditions System

Pro-Vision, 2026
https://provisionsolutions.com/
From the website: From our state-of-the-art video recording systems to real-time data monitoring and sophisticated cloud storage, Pro-Vision helps you increase productivity, enhance safety and protect critical assets.

Noted products: Cameras

RoadWatch/Commercial Vehicle Group Inc., 2026.
https://roadwatch.com/
From the website: We are known for road surface temperature sensors that use state-of-the-art infrared measuring technology. This provides accurate, real-time road surface temperature information critical to proper deployment of anti-icing and de-icing materials.

Noted product: RoadWatch Sensor Kit

Samsara, Inc. 2026.
https://www.samsara.com/
From the website: Samsara's platform leverages AI and data from your physical operations — vehicles, equipment and sites — to provide actionable insights.

- Universal data integrations
- Real-time asset and vehicle visibility
- Predictive maintenance and automated work orders
- Route optimization and live ETAs [estimated time of arrival]

Noted products:

- Dual-facing AI dash cam: HW-CM34
- Front-facing AI dash cam: CM33
- Vehicle Gateway VG-54

See also:

- Fleet telematics
- Cameras and video
- Equipment management

Samsung, 2026.
https://www.samsung.com/us/

Noted products:

- A9 Plus Tablet
- A11 Plus Tablet

Vaisala, 2026.
https://www.vaisala.com/en
From the website: Our reliable measurements turn into trustworthy data. Data drives insights and insights lead to better decisions. Our weather and industrial solutions and services support authorities, industries and innovators around the world to act with confidence, even in the most demanding environments.

Noted product: Mobile Detector MD30

Verizon, 2026.
https://www.verizonconnect.com/
From the website: Track vehicles in the field, improve fleet operations, increase worker productivity and safe driving with Verizon Connect fleet management solutions. Choose from a range of customizable GPS tracking solutions that offer dashboards, reports and alerts.

Noted product: Verizon Connect fleet management software

ZenduIT, undated.
https://zenduit.com/
From the website: For the past decade, ZenduIT has led the charge in revolutionizing fleet management with innovative, next-generation solutions.

Noted product: ZenduCAM LITE: Single and dual channel dash cameras

Appendix A: Survey

The survey below was provided in an online format to Clear Roads members and selected voting members of the AASHTO Committee on Maintenance.

Describing AVL/GPS Systems

(Required) Is your agency currently using an AVL/GPS system to automate the collection of data for winter maintenance operations?

- Yes (Directs the respondent to **Question 1** below and the remaining questions in the survey, if applicable.)
- No, but we have interest in implementing this technology. (Directs the respondent to **Interest in AVL/GPS Systems** and **Wrap-Up**.)
- No, and we have no interest in implementing this technology. (Directs the respondent to **Wrap-Up**.)

1. What is the total count for your winter heavy-duty plow-equipped fleet?
2. What percentage of your heavy-duty plow-equipped fleet is outfitted with AVL/GPS technology?
3. Does your agency install AVL/GPS systems on equipment other than heavy-duty plow trucks?
    - No
    - Yes (Please describe the other types of equipment your agency has equipped with AVL/GPS technology.)
4. Please provide the make and model, if available, of the plow trucks that are equipped with AVL/GPS systems.
5. Please identify up to five AVL/GPS system manufacturers and models your agency uses and the number of installations for each AVL/GPS system.
    - Manufacturer/Model 1 and Number of Installations:
    - Manufacturer/Model 2 and Number of Installations:
    - Manufacturer/Model 3 and Number of Installations:
    - Manufacturer/Model 4 and Number of Installations:
    - Manufacturer/Model 5 and Number of Installations:
6. If your agency uses more than one make or model of AVL/GPS system, please briefly describe any challenges your agency has encountered as a result of using multiple systems.
7. Has your agency made a systemwide change in AVL/GPS system make or model?
    - No
    - Yes (Please identify the current and previous AVL/GPS systems and describe why the change was made.)
8. Please identify the purposes for which your agency's AVL/GPS system gathers data for winter maintenance operations by selecting all that apply.
    - Collection of vehicle diagnostic data
    - Humidity reporting
    - Material usage tracking and analysis
    - Plow status (up/down)
    - Road condition reporting
    - Route planning and optimization
    - Sharing of images or video on web page
    - Sharing of vehicle location through agency traveler information system
    - Temperature reporting
    - Time roadway last plowed and material applied

- Vehicle location tracking or fleet monitoring
- Other (Please describe other purposes for your agency's AVL/GPS system.)

9. Who installed the AVL/GPS equipment?
10. Who maintains the AVL/GPS equipment?
11. Does your agency pay any ongoing fees associated with your agency's most typical AVL/GPS system(s)?
    - No
    - Yes (Please describe what the ongoing fees cover. For example, standard monthly or annual fees, maintenance issue fees, or other types of fees.)
12. Does your agency plan to expand the use of AVL/GPS technologies on winter maintenance vehicles?
    - No
    - Yes (Please describe your agency's plans to expand use of AVL/GPS technologies on winter maintenance vehicles.)

Maintaining AVL/GPS Systems

1. What is the failure rate, if known, for your AVL/GPS systems?
2. Please describe typical repair costs for the AVL/GPS equipment.
3. Please describe your agency's experience regarding system downtime and turnaround time for repair.
4. Please describe vendor responsiveness when reporting system issues or downtime.

Describing Auxiliary Equipment

1. Please describe the auxiliary equipment integrated with the AVL/GPS system, including brands and models, if possible.
    - Dashboard cameras (front, rear or other)
    - Material spreader controllers
    - Mobile data terminal or computer
    - Pavement sensors
    - Plow controllers or position sensors
    - Weather sensors
    - Other auxiliary equipment
2. Has your agency encountered difficulties installing or connecting the auxiliary equipment to the AVL/GPS system?
    - No
    - Yes (Please describe the difficulties your agency experienced installing or connecting the auxiliary equipment to the AVL/GPS system.)
3. Has your agency experienced difficulties with the operational compatibility between the auxiliary equipment and AVL/GPS system?
    - No
    - Yes (Please describe the difficulties your agency experienced with the operational compatibility between the auxiliary equipment and AVL/GPS system.)
4. Please describe any data transfer issues that your agency has identified when moving data to and from the AVL/GPS system.

5. Do the vehicle makes and models present any challenges when installing or operating AVL/GPS systems? Challenges could involve, for example, incompatibilities with a truck's on-board diagnostic computer.
    - No
        - Yes (Please describe any challenges installing or operating AVL/GPS systems arising from the make or model of agency vehicles.)

Describing AVL/GPS Data Collected

1. Please identify how your agency uses the data collected from AVL/GPS systems by selecting all that apply.
    - Analyze winter maintenance operations after winter weather events
    - Inventory liquid or solid material used on roadways
    - Operational analysis, evaluation and performance reporting
    - Provide data to a maintenance decision support system (MDSS)
    - Track and adjust application rates or amounts of liquid or solid material used on roadways
    - Other (Please describe other current uses of AVL/GPS data.)
2. Has your agency identified issues with data accuracy for any of the uses of AVL/GPS system data you previously identified?
        - No
        - Yes (Please describe the data accuracy issues your agency has experienced.)
3. If your agency has identified data inaccuracies with AVL/GPS systems, please describe the source or reasons for data inaccuracies, if known.
4. Has your agency identified solutions for any data accuracy issues experienced with AVL/GPS systems?
        - No
        - Yes (Please describe the solutions for these data accuracy issues.)
5. Please describe how the data generated by your AVL/GPS system is stored.
6. Who is responsible for managing the data generated by your AVL/GPS system?
7. Please describe any future uses of AVL/GPS data your agency is preparing for or hopes to implement.

Assessment

1. Please briefly describe the top three benefits of using AVL/GPS systems in winter maintenance operations.

    Benefit 1:
    Benefit 2:
    Benefit 3:
2. Please briefly describe the top three challenges your agency has encountered when using AVL/GPS systems in winter maintenance operations.

    Challenge 1:
    Challenge 2:
    Challenge 3:
3. What are the best practices or lessons learned your agency has identified after installing and operating AVL/GPS systems for winter maintenance purposes?

4. Please provide links to documents associated with your agency's AVL/GPS system installations. Send any files not available online to susan.johnson@ctcandassociates.com.

Interest in AVL/GPS Systems

1. Please identify the purposes for which you anticipate your agency might use an AVL/GPS system to gather data for winter maintenance operations. Select all that apply.
    - Collection of vehicle diagnostic data
    - Humidity reporting
    - Material usage tracking and analysis
    - Road condition reporting
    - Route planning and optimization
    - Sharing of images or video on web page
    - Sharing of vehicle location through agency traveler information system
    - Temperature reporting
    - Vehicle location tracking or fleet monitoring
    - Other (Please describe other purposes anticipated for an AVL/GPS system.)
2. Please describe any barriers to using AVL/GPS systems for your agency's winter maintenance operations.
3. When do you anticipate implementing AVL/GPS technology?

Wrap Up

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

Appendix B: Agency Vehicles Equipped With AVL/GPS

The tables below summarize data regarding responding agencies' fleets and how they are outfitted with AVL/GPS.

Alaska Department of Transportation and Public Facilities

Topic	Description
Heavy-Duty Plow-Equipped Fleet Count	Not provided
Truck Make and Model	• International HV13 • Mack Granite
Percentage of Fleet With AVL/GPS	Over 70 trucks
Other Vehicles Equipped With AVL/GPS	Some graders and sanders

Connecticut Department of Transportation

Topic	Description
Heavy-Duty Plow-Equipped Fleet Count	645
Truck Make and Model	• Freightliner • International • Mack • Peterbilt • Volvo
Percentage of Fleet With AVL/GPS	265; will be fleetwide in summer 2026
Other Vehicles Equipped With AVL/GPS	• All light-duty vehicles being equipped in 2026 • Service patrol assistance trucks • Sweepers • Vacuum trucks

Delaware Department of Transportation

Topic	Description
Heavy-Duty Plow-Equipped Fleet Count	330
Truck Make and Model	• Freightliner • International
Percentage of Fleet With AVL/GPS	100%
Other Vehicles Equipped With AVL/GPS	• Light-duty vehicles • Tractors, tractor trailers and sweepers

Iowa Department of Transportation

Topic	Description
Heavy-Duty Plow-Equipped Fleet Count	920

Topic	Description
Truck Make and Model	International
Percentage of Fleet With AVL/GPS	100%
Other Vehicles Equipped With AVL/GPS	• Heavy-duty snowblowers (10) • Cable guard mowers (3)

Kansas Department of Transportation

Topic	Description
Heavy-Duty Plow-Equipped Fleet Count	591
Truck Make and Model	• Freightliner • International • Sterling
Percentage of Fleet With AVL/GPS	100%
Other Vehicles Equipped With AVL/GPS	Some headquarters cars

Maine Department of Transportation

Topic	Description
Heavy-Duty Plow-Equipped Fleet Count	430 (approximately)
Truck Make and Model	All
Percentage of Fleet With AVL/GPS	100%
Other Vehicles Equipped With AVL/GPS	All light fleet vehicles, car and pickups

Massachusetts Department of Transportation

Topic	Description
Heavy-Duty Plow-Equipped Fleet Count	2,847
Truck Make and Model	• Freightliner • International • Mack • Peterbilt • Volvo
Percentage of Fleet With AVL/GPS	44%
Other Vehicles Equipped With AVL/GPS	Light-duty pickups and fleet vehicles

Michigan Department of Transportation

Topic	Description
Heavy-Duty Plow-Equipped Fleet Count	385 (approximately)

Topic	Description
Truck Make and Model	• International • Western Star
Percentage of Fleet With AVL/GPS	100%
Other Vehicles Equipped With AVL/GPS	• Woodchippers • Herbicide sprayers

Minnesota Department of Transportation

Topic	Description
Heavy-Duty Plow-Equipped Fleet Count	893
Truck Make and Model	• Freightliner 114SD • International 7500 and 7600 • Sterling LT9511 and L8511 • Western Star 470SF, 47X and 49X
Percentage of Fleet With AVL/GPS	97%
Other Vehicles Equipped With AVL/GPS	Passenger cars and trucks

Nebraska Department of Transportation

Topic	Description
Heavy-Duty Plow-Equipped Fleet Count	655
Truck Make and Model	• Freightliner 114SD • International 7600, SFA 6X4 and 7400 SFA • Sterling LT9500, T7500, LT9511 and LT7501 • Western Star 4700SF
Percentage of Fleet With AVL/GPS	100%
Other Vehicles Equipped With AVL/GPS	Light-duty vehicles, on a limited basis

Nevada Department of Transportation

Topic	Description
Heavy-Duty Plow-Equipped Fleet Count	188
Truck Make and Model	• International 2574 • Mack RD688S • Peterbilt 357 and 367 • Western Star 4900, 4900FA, 4900SF and 49X
Percentage of Fleet With AVL/GPS	90%
Other Vehicles Equipped With AVL/GPS	• Entire light-duty fleet (sedans, SUVs and pickup trucks) • One-ton through Class 8 trucks

New Jersey Department of Transportation

Topic	Description
Heavy-Duty Plow-Equipped Fleet Count	530
Truck Make and Model	• International 7400 and STF 4x2 • Volvo VHD64F
Percentage of Fleet With AVL/GPS	100%
Other Vehicles Equipped With AVL/GPS	• All vehicles • Most loaders and tractors • Some specialty trailer and message boards

Ohio Department of Transportation

Topic	Description
Heavy-Duty Plow-Equipped Fleet Count	1,650 (approximately)
Truck Make and Model	• Freightliner • International • Mack • Western Star
Percentage of Fleet With AVL/GPS	100%
Other Vehicles Equipped With AVL/GPS	Small fleet uses Geotab.

Oklahoma Department of Transportation

Topic	Description
Heavy-Duty Plow-Equipped Fleet Count	733
Truck Make and Model	• Freightliner • International • Western Star
Percentage of Fleet With AVL/GPS	85-90%
Other Vehicles Equipped With AVL/GPS	Superintendents' pickups (supervisors of snowplow operations).

Oregon Department of Transportation

Topic	Description
Heavy-Duty Plow-Equipped Fleet Count	465
Truck Make and Model	Volvo VHD
Percentage of Fleet With AVL/GPS	99%

Topic	Description
Other Vehicles Equipped With AVL/GPS	• Light- and medium-duty fleet sweepers • Vactor trucks • Mowers • Loaders • Snowblowers

Pennsylvania Department of Transportation

Topic	Description
Heavy-Duty Plow-Equipped Fleet Count	2500
Truck Make and Model	• Ford • International • Mack • Peterbilt • Western Star
Percentage of Fleet With AVL/GPS	100%
Other Vehicles Equipped With AVL/GPS	• Foreman crew cabs and manager vehicles • Paint trucks and bridge inspection trucks

South Dakota Department of Transportation

Topic	Description
Heavy-Duty Plow-Equipped Fleet Count	328
Truck Make and Model	• Freightliner SD114 • International • Mack GU713 • Sterling
Percentage of Fleet With AVL/GPS	90%
Other Vehicles Equipped With AVL/GPS	The agency does not install AVL/GPS systems on equipment other than heavy-duty plow trucks.

Tennessee Department of Transportation

Topic	Description
Heavy-Duty Plow-Equipped Fleet Count	850
Truck Make and Model	• Freightliner • International • Mack
Percentage of Fleet With AVL/GPS	100%
Other Vehicles Equipped With AVL/GPS	"Everything with wheels or a motor."

Vermont Agency of Transportation

Topic	Description
Heavy-Duty Plow-Equipped Fleet Count	254
Truck Make and Model	• Freightliner • International
Percentage of Fleet With AVL/GPS	100%
Other Vehicles Equipped With AVL/GPS	Complete fleet has AVL/GPS installed, from SUVs to light-duty pickup trucks to construction equipment.

Wyoming Department of Transportation

Topic	Description
Heavy-Duty Plow-Equipped Fleet Count	374
Truck Make and Model	• Freightliner 114SD (year models between 2011 – 2026) • International 7600 (2009) • Mack GR64R (2020, 2023); GUR64R (2018); GU713 (2014)
Percentage of Fleet With AVL/GPS	Approximately 85%
Other Vehicles Equipped With AVL/GPS	• Many vehicles have Motorola radios with AVL capability. • GIS/ITS fleet and maintenance fleet units have AVLs. • Some vehicles are equipped with Samsung tablets with cellular service, which are also used as AVLs.

research for winter highway maintenance

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