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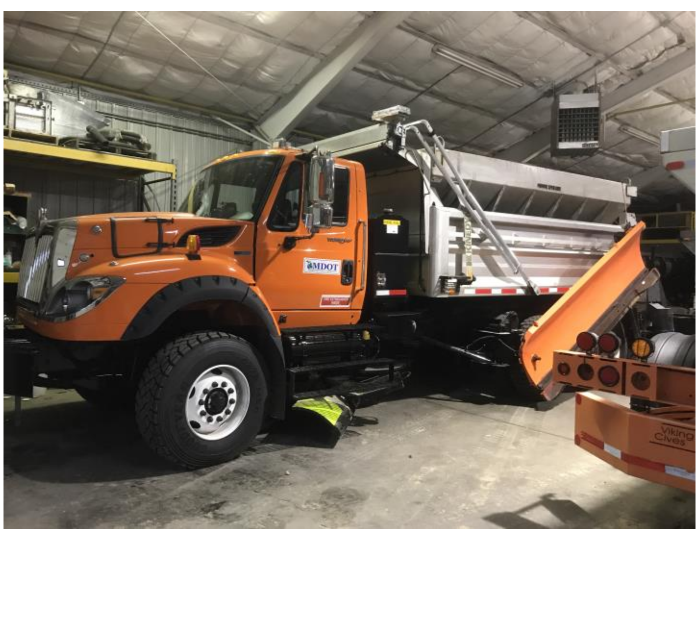
Utilization of AVL/GPS Technology Case Study: Michigan Department of Transportation

Clear Roads Project 16-01: Utilization of AVL/GPS Technology: Case Studies



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16. Abstract

Winter road maintenance accounts for roughly 20 percent of state DOT maintenance budgets. State and local agencies spend over $2.3 billion on winter operations annually. As such, effective winter maintenance operations incorporating smart uses of methods, techniques, technologies, equipment and materials becomes essential. Among various winter maintenance technologies, automated vehicle location (AVL) and global positioning systems (GPS) have been widely used by transportation agencies to monitor vehicle locations and equipment operational status for winter road maintenance operations.

This document is one of the six case studies conducted for the Clear Roads project entitled *Utilization of AVL/GPS Technology: Case Studies*. This case study report summarizes Michigan Department of Transportation's experiences and lessons learned in using AVL/GPS technologies for winter maintenance. The case study took a broad view, examining agencies' decision-making processes; implementation steps; difficulties and lessons learned; and documented benefits and costs for different tiers of AVL/GPS implementation.

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1. Overview of Michigan DOT Winter Maintenance Operations

This section provides an overview of this Case Study report detailing how the Michigan Department of Transportation (MDOT) has implemented Automated Vehicle Locator (AVL) / Global Positioning Systems (GPS) technologies on its winter maintenance vehicles for use in monitoring the operations of snow plow vehicles.

1.1 Case Study Background

This research project is being funded through the Clear Roads pooled fund program to develop Case Study Reports documenting how multiple State DOTs have implemented AVL/GPS technologies to support their winter maintenance programs. While the main function of the system is to provide automated vehicle location tracking for dispatchers and maintenance supervisors, AVL/GPS systems can also provide valuable information on vehicle diagnostics to maintenance supervisors. Furthermore, AVL/GPS systems can be integrated with existing vehicle components used for snow plow operations, such as spreader controllers and plow blades to provide reports to maintenance supervisors on plow usage and material applied by snow plow operators.

The purpose of the Case Study reports is to help other state DOTs make more informed decisions with respect to the implementation of AVL/GPS technology for winter maintenance activities. The case study report is intended to bring to light more nuanced issues related to the use of AVL/GPS technology for winter maintenance. The Case Study report also highlights the types of issues other state DOTs / agencies should consider prior to system procurement, provides guidance for successful implementation of the technology, and serves as a possible template for agencies to get the best value out of different levels their AVL/GPS applications.

In the spring of 2017, a survey was distributed to multiple state DOTs to gather basic, high-level information regarding each agency's level of AVL/GPS implementation, as well as detailed information on the planning, processes, steps, and results observed by agencies with their respective systems. Based on the survey responses, agencies were categorized into the following three levels of AVL/GPS implementation:

- Tier 1: Basic Location Tracking/Monitoring with or without collection of vehicle diagnostic data
- Tier 2: Medium implementation with basic location tracking, with limited additional data collection, equipment integration, and system reporting features
- Tier 3: High implementation with added, more complex data collection, integration, and reporting features

Upon a review of these survey responses, six agencies representing various tiers of implementation were selected to more in-depth interviews and for case studies. The MDOT was categorized into Tier 2 and ultimately selected for further in-depth interviews to gather more information on how their AVL/GPS system is implemented and utilized. MDOT's survey responses are included in Appendix A of this Case Study.

1.2 Agency Characteristics

MDOT is divided into seven different regions as shown in Figure 1. MDOT uses both MDOT Direct Forces and contract county agencies to perform winter maintenance activities on Interstates and State routes. MDOT winter maintenance personnel operate out of the Region and Transportation Service

Center (TSC) offices and perform snow plowing on Interstates and State routes within each region. MDOT contracts individually with many counties in the state as well to perform winter maintenance. In general, MDOT Direct Forces perform snow plow operations on about 30% of the Interstates and State routes within the state, while Counties maintain the other 70%, as shown in Figure 2.

On average, MDOT spends roughly $100 million on winter maintenance each season, which represents approximately forty percent of its total maintenance budget.[1]

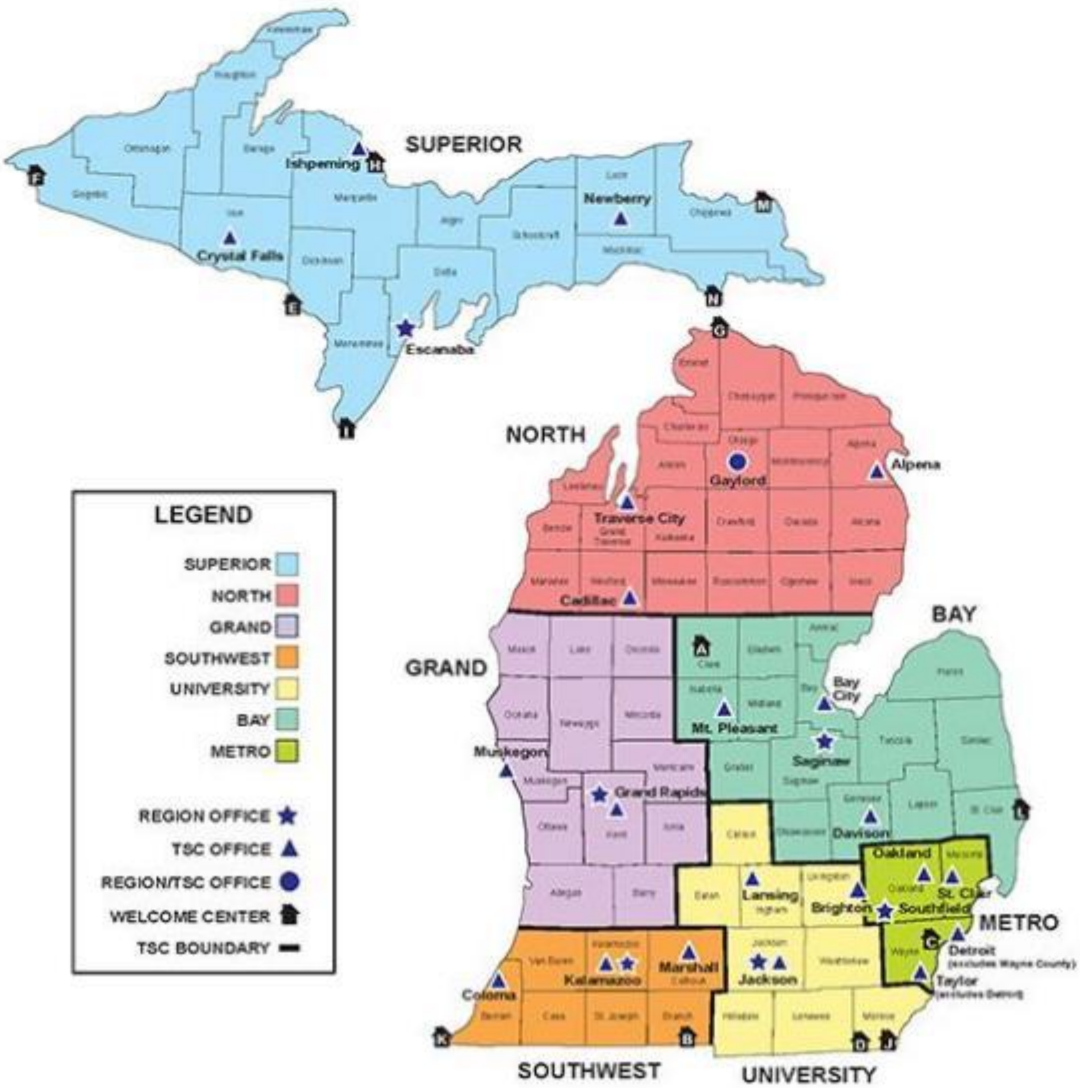


Figure 1. MDOT Regions[2]

[1] Source: https://ops.fhwa.dot.gov/weather/best_practices/casestudies/015.pdf
[2] Source: http://www.michigan.gov/mdot/0,4616,7-151-9623-36042--,00.html

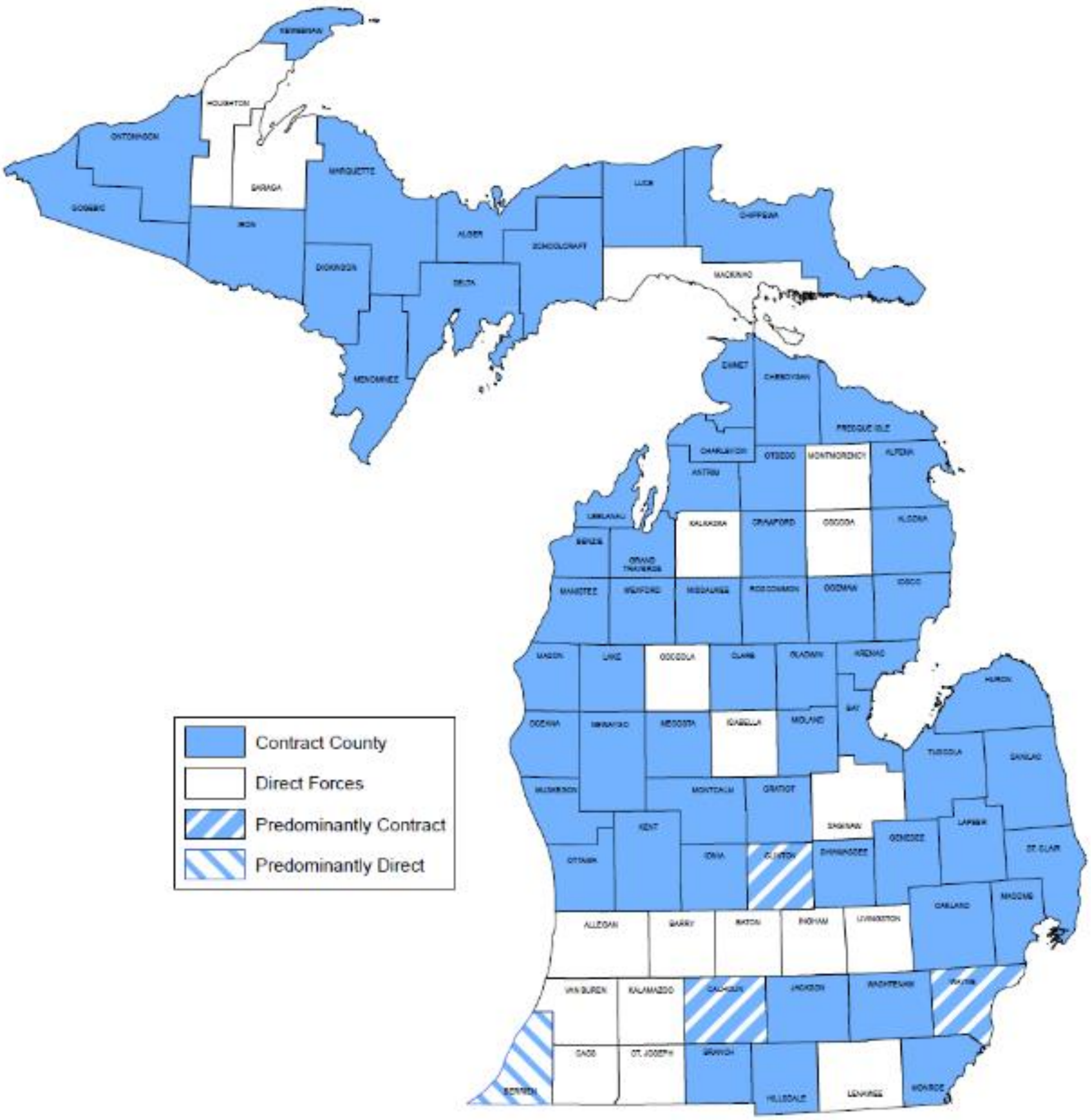


Figure 2. MDOT and County Partnership

1.3 Agency Interviews

MDOT staff were interviewed on Nov. 30th, 2017 at MDOT offices in and around Lansing, MI. Table 1 lists those individuals that were interviewed for the project.

Table 1. Agency Interview Dates / Times

Staff Interviewed	Date / Time	Subjects Discussed
Melissa Longworth, Michigan DOT **Ben Hodges**, MDOT Maintenance Supervisor **Mark Crouch**, MDOT Maintenance Coordinator **Matthew Pratt**, MDOT Maintenance Coordinator	Nov. 30th / 7:30am	Hardware installation Technology issues and testing Operations Maintenance
Melissa Longworth, Michigan DOT **Matthew Pratt**, MDOT Maintenance Coordinator **Greg Perry**, MDOT Operations Engineer **Tim Croze**, MDOT Manager of Maintenance Services **Justin Droste**, MDOT Asset Management Engineer **Sean Mulligan**, Parsons Software Support	Nov. 30th / 10:00am	Implementation and Integration Decisions Hardware and Software Selection Data Collection, Utilization and Management Communications Implementation Issues Operations Issues Procurement Costs and Benefits Recommendations and Lessons Learned

2. Degree of AVL/GPS Implementation

2.1 AVL/GPS Project Background

MDOT executive management expressed a desire to investigate AVL/GPS systems in early 2013 and requested operations and maintenance staff to review available system options. MDOT surveyed other states through the Clear Roads program and also through the Maintenance Decision Support System (MDSS) Pooled Fund studies on lessons learned in the overall process.

One of the lessons gathered by MDOT was related to the challenges of managing separate contracts for both an AVL/GPS system and an MDSS provider, in addition to other contracts for cellular equipment, could create issues with the coordination required between multiple contractors for implementation and integration. From this research, MDOT determined to proceed with the procurement of a single contractor that would be responsible and accountable for the management of both the AVL/GPS system and the MDSS system implementation and operations.

2.2 Size of AVL/GPS Implementation

MDOT has procured and installed AVL/GPS equipment on all of its snow plow trucks (approximately 340) throughout the state. As noted previously, MDOT also contracts with Counties throughout the State to perform winter maintenance on Interstates and State routes. The procurement was for MDOT owned snow plow vehicles only and didn’t include any County-owned snow plows.

MDOT has also integrated the AVL/GPS system hardware on its snow plows with the following on-board winter maintenance equipment:

- DICKEY-john ControlPoint spreader controllers
- RoadWatch pavement temperature sensors
- Wing plow position sensors
- Tow plow position sensors,
- Gate sensors,
- Hydraulic meter sensors, and
- Front-facing Logitech vehicle dash-cams.

The AVL hardware is also connected to the existing vehicle on-board diagnostics port (OBD-II port) for reading vehicle diagnostic codes.

2.3 AVL/GPS Vendor Solution

MDOT selected Parsons as the vendor that was responsible for providing the AVL/GPS hardware and software, as well as for the management of the system's integration with the MDSS software provided by Iteris. Parsons subcontracted with Iteris for MDSS services, Verizon for communication services, and partnered with DICKEY-john for spreader controller integration.

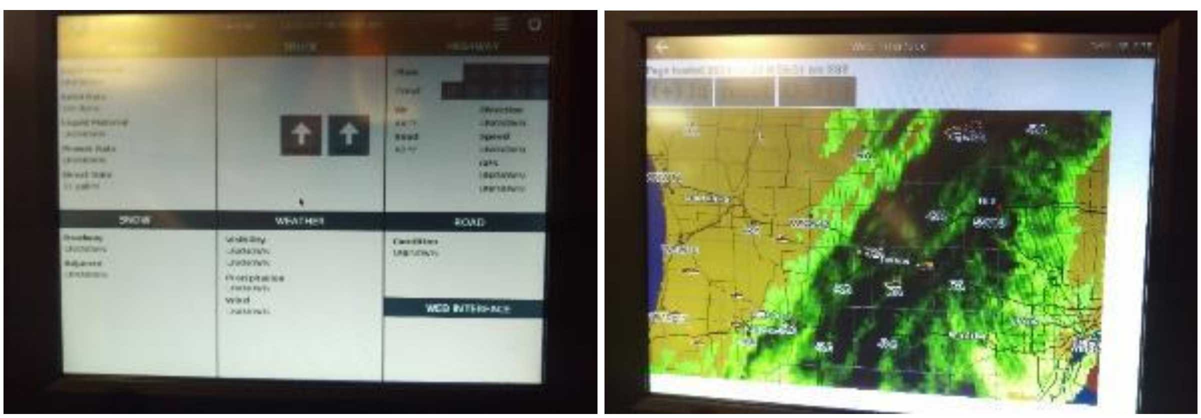
3. Level of System Integration

3.1 Vehicle Hardware

The vehicle hardware component of the MDOT AVL/GPS is the Parsons MDC-004 hardware which includes a touch screen and hardware as pictured in Figures 3 and 4. The hardware or the "black box" contains the cellular modem, power supply, and computer processor to collect and process data from all other vehicle equipment, such as spreader controllers and plow position sensors. This hardware is generally installed behind the driver seat or the passenger seat of the vehicle and attached to the vehicle in an upright position to allow for access to the cabling leading to the hardware. Figure 5 illustrates some of the views on the touch screen that are available to drivers within the cab of the vehicle.

Figure 3. Mobile Data Computer (MDC) and AVL Hardware (above) and Back View of MDC, Antennae and Cable (below)

Figure 4. Location of Parsons AVL Hardware in MDOT Snow Plow



Review Screen ***Weather Radar View***

Figure 5. Touch Screen of the AVL System

As noted previously, the AVL hardware was integrated with the following equipment for data reporting:

- DICKEY-john ControlPoint spreader controllers
- RoadWatch pavement temperature sensors
- Wing plow position sensors
- Tow plow position sensors,
- Gate sensors,
- Hydraulic meter sensors,
- OBD-II port, and
- Front-facing Logitech vehicle dash-cams.

Figure 6. DICKEY-john Spreader Controller Screen in MDOT Snow Plow Vehicle

The RoadWatch pavement temperature sensors are mounted on the exterior of the vehicle with wires tied to side view mirror. Cabling is run through the vehicle and into the vehicle where it connects with the AVL hardware.

Figure 7. RoadWatch Pavement Temperature Sensors on MDOT Snow Plow Vehicle

Images of an MDOT wing plow and tow plow are provided in the Figure 8. A mercury sensor indicates the position of the plow, whether up or down, and the sensor is then wired into the AVL hardware. MDOT snow plows also feature under-belly plow blades for snow clearance. Given the effectiveness of these plow blades, MDOT snow plow vehicles do not have any front-mounted plows like many other agencies.

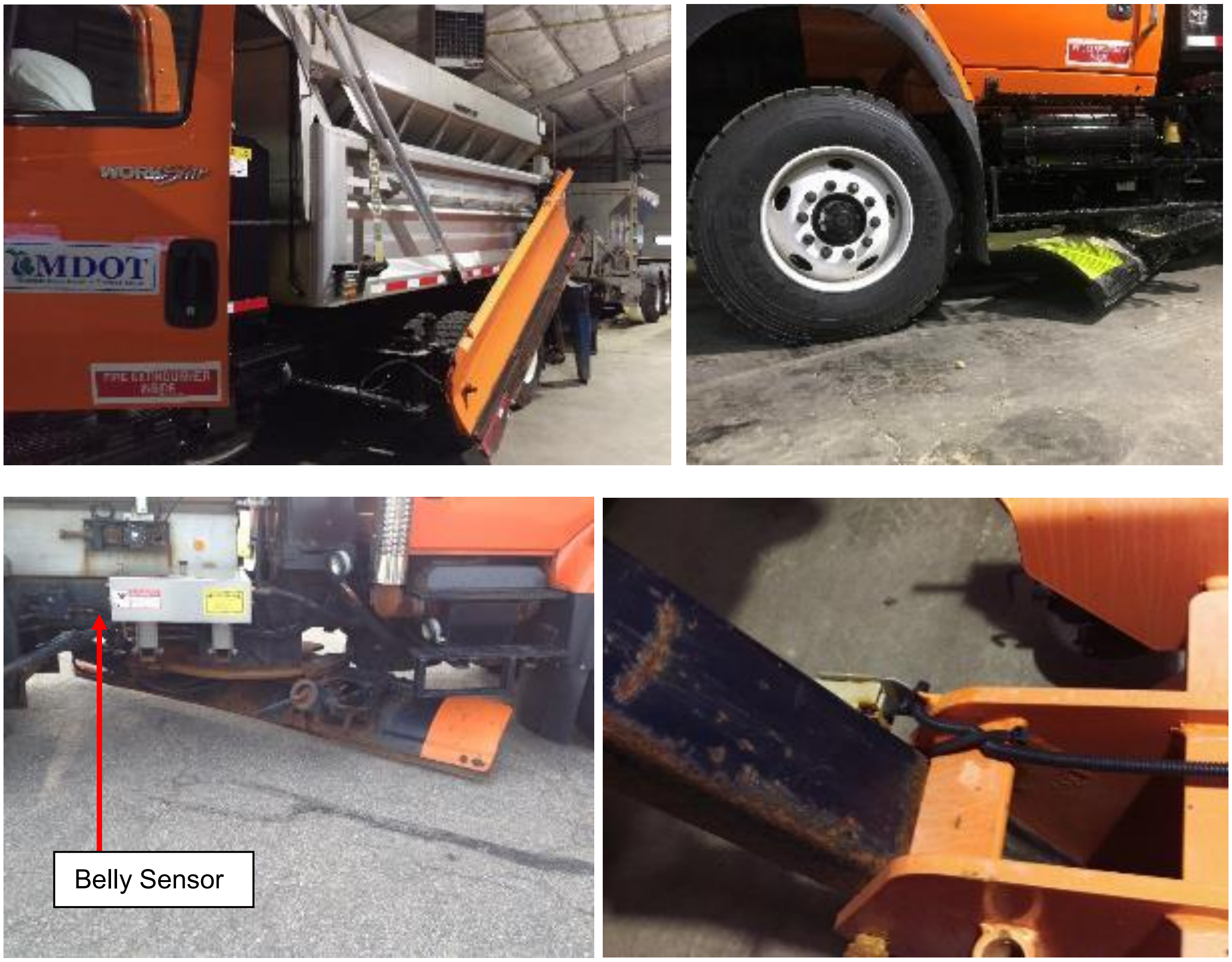


Figure 8. Wing Plow and Under-Belly Plow (above) and Belly Sensor and Tow Plow Sensor (below)

MDOT staff noted that vehicle camera images are taken once a minute and those pictures then appear within the AVL / MDSS software interfaces for review by MDOT maintenance supervisors. The cameras are manufactured by Logitech and are provided by Parsons for installation by MDOT vehicle staff. The dash-cams are also wired into the AVL hardware for sending images taken once a minute.

Figure 9. MDOT In-Vehicle Camera Image of Snow Plow Operations

3.2 System Software and Interface

MDOT utilizes two separate software packages that are described further within this section: one for the AVL/GPS system provided by Parsons, and a separate software interface for the MDSS functionality provided by Iteris.

3.2.1 AVL/GPS System Software

The AVL software package presents a map-based interface that allows MDOT staff to view the locations of snow plow vehicles in the field, which can be filtered in multiple ways (i.e. by region, by county, etc.…). The interface allows for selecting specific vehicles on the map and viewing information about that specific vehicle.

MDOT staff noted that the map-based interface is not as user-friendly as other Windows-based interfaces, and requires training on how to navigate through various features. Snow plow locations are also shared with the public-facing MiDrive traffic information website that presents traffic and roadway information with the general public. It was noted that there is a small lag of about three to five minutes of when vehicle locations are reported.

The AVL software can run automated reports that can assist maintenance staff to identify when issues may be occurring with AVL hardware. The reports can be custom-developed to provide alerts on items of interest for maintenance staff, which can assist in preventative maintenance of the vehicles. Through the software, MDOT staff can use a filter to view snow plow vehicles at specific garages and then view the date and time stamps of specific data elements. The absence of any data in the software reported from a vehicle is often a quick way to identify when antennae may not be functioning or when AVL hardware may be malfunctioning. MDOT maintenance staff can then review that specific vehicle and perform the needed repairs, or request assistance from the AVL vendor as needed if replacement parts are required.

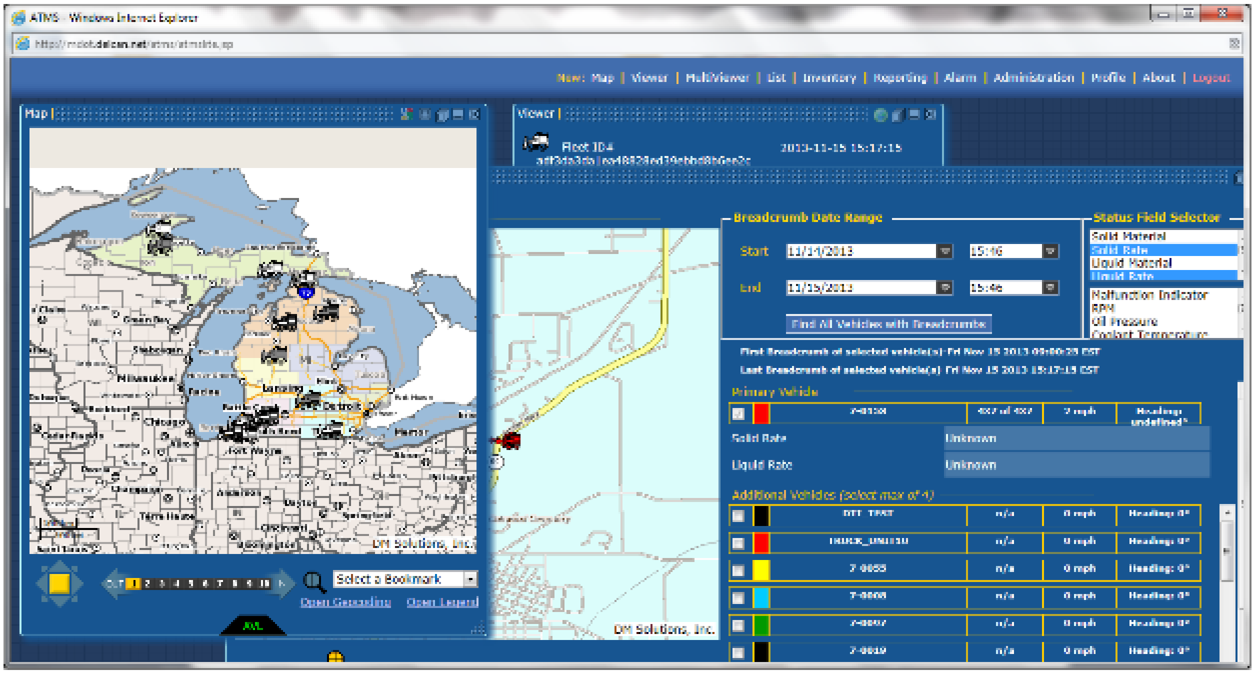


Figure 10. Parsons AVL System Interface Graphic

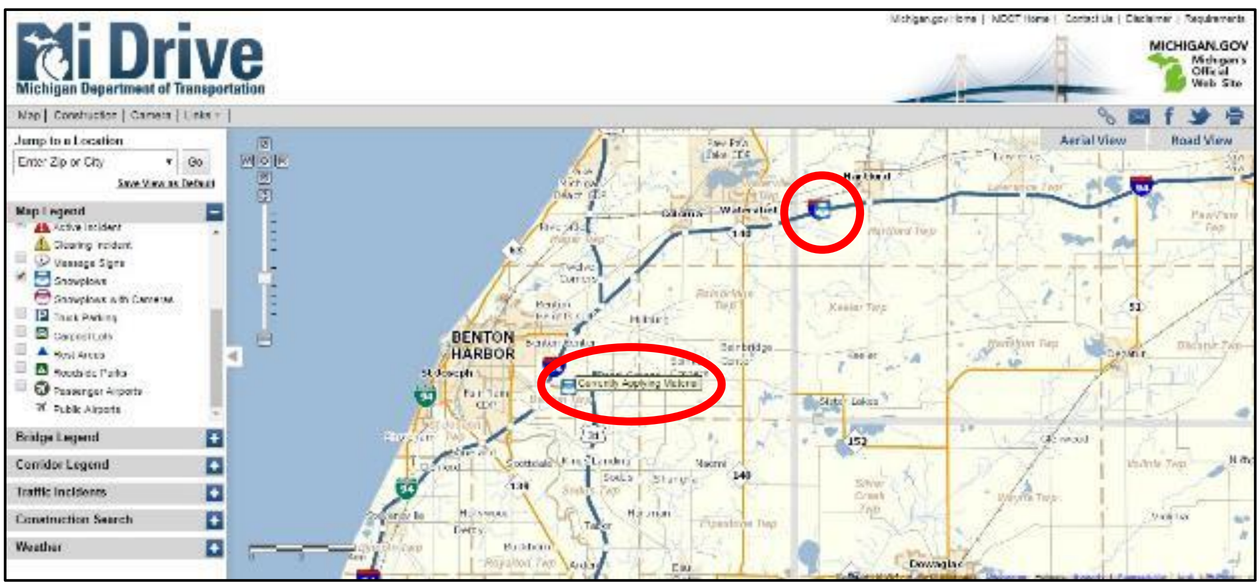


Figure 11. MDOT MiDrive Public Website with AVL Vehicle Locations Shown (Circled)

The most frequently used reports by MDOT staff include reports for blade usage, material usage, and speed compliance. The speed compliance report is an example of a custom-developed report for MDOT that can indicate the speeds of snow plows as they apply material. A recent MDOT study has found that 25 MPH is the ideal speed to ensure that salt remains on the road and does not scatter outside of the travel lanes. Reports on snow plow drivers can be generated for instances where speeds are detected in excess of 25 MPH. The reports can be used to discuss best practices with the drivers about maintaining travel speeds in the desired 25 MPH range.

The structure of this speed compliance report, and other reports within the AVL system, were requested by MDOT to be provided by the AVL vendor (Parsons) for future analyses by MDOT staff. These reports also help ensure the efficiency of snow plow operations.

3.2.2 MDSS Software

The MDSS software interface provided by Iteris is used for monitoring weather forecasts and determining the most efficient times and locations for roadway treatment. Multiple types of alerts can be presented on upcoming weather, road conditions, and where blowing snow would be predicted, along with maintenance alerts that provided treatment recommendations on material to be applied to specific roadways.

MDOT archives its previous treatment for the past 24 hours and can look ahead to the next 24 hours as well and see how past roadway treatment may be impacting recommendations, since a comparison of "no treatment" is presented alongside the current treatment by MDOT. It was also noted that the mobile application has been more useful to snow plow drivers than the laptop / PC-based version given that drivers do have mobile devices for viewing the interface in the field.

MDOT staff noted that the integration of the AVL functionality and vehicle locations within the MDSS software package provides MDOT maintenance supervisors and operations staff with the most effective tool for responding to winter weather events. MDOT staff noted that only a handful of states have performed the integration given the integration effort involved, but that it has proven to be effective for winter maintenance operations.

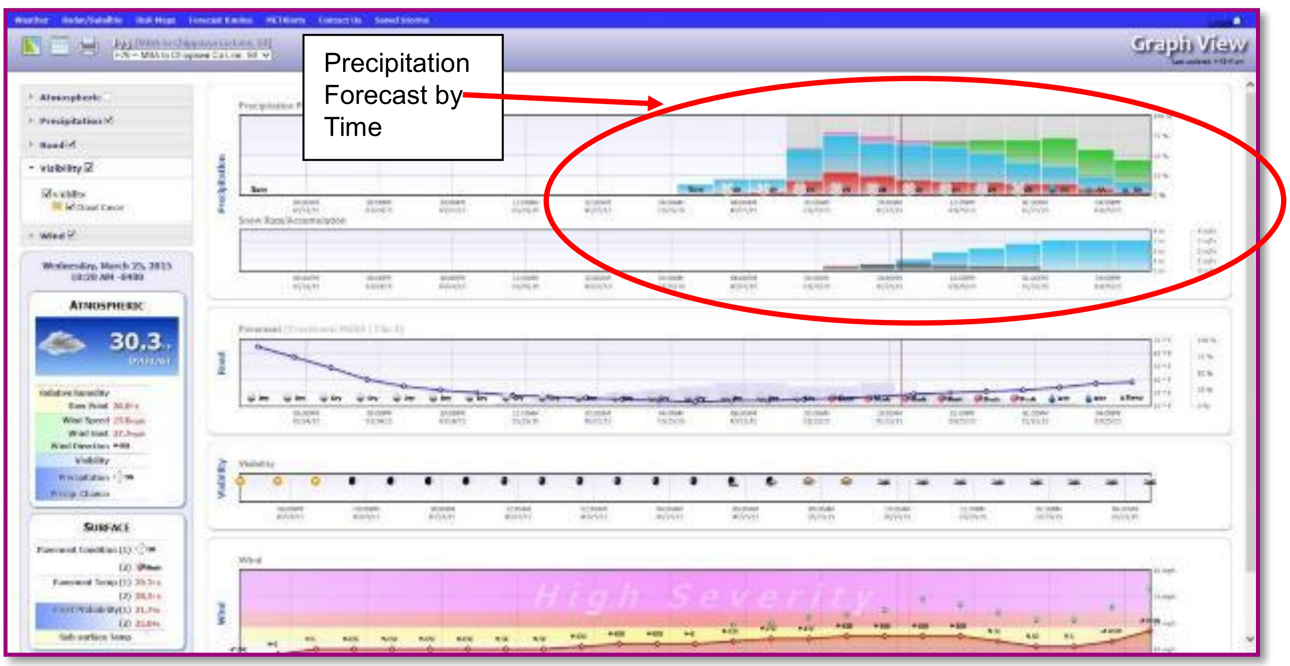


Figure 12. MDSS Screenshot of Weather Forecast

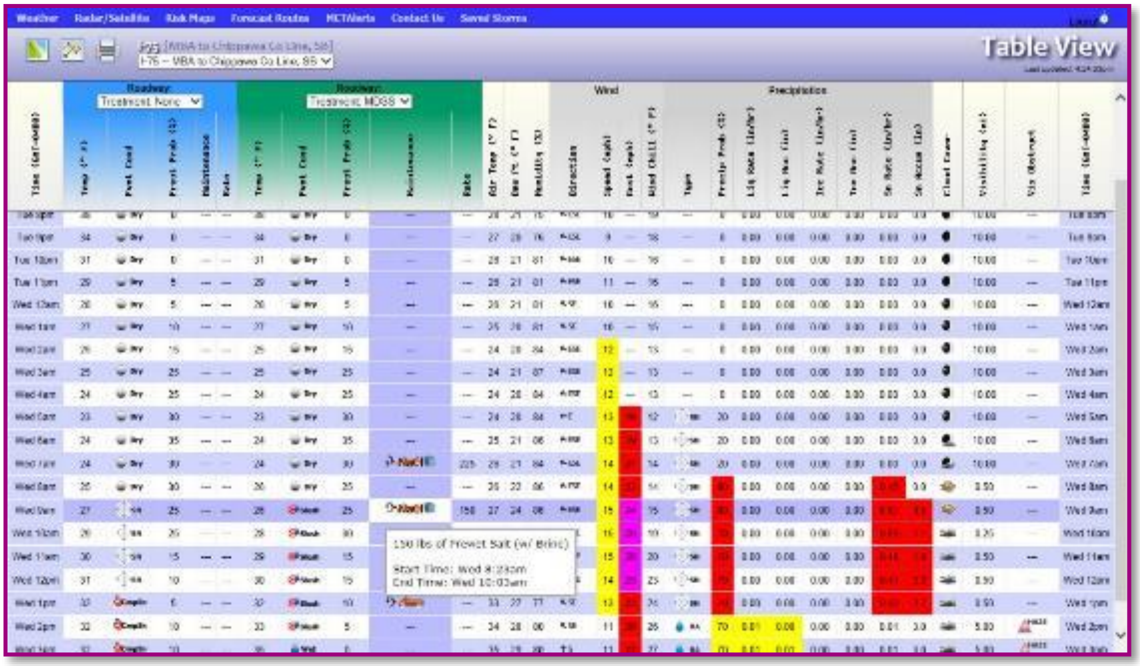


Figure 13. Iteris MDSS Screenshot

3.3 Vehicle-to-Center Communications

The AVL hardware is equipped with a cellular modem for the purpose of communicating vehicle location and other data gathered in the AVL system to the servers that store data for presentation on the AVL software package. A cellular antenna is also installed on the roof of the vehicle and wired into the AVL hardware inside the vehicle.

It was noted by MDOT staff that the cellular service provided covers all the of MDOT maintenance areas. In the event of any gaps in cellular coverage, the AVL hardware stores any data that is gathered and then forwards the data once is it is back within cellular coverage.

4. System Decision Making Processes

4.1 Level of Management Involved

The main impetus behind MDOT's AVL and MDSS implementation was to provide a tool to allow maintenance garage supervisors to make more informed decisions on attacking winter storms using real-time operational data, current and forecasted weather information and scientific models that predicts how the forecasted weather would affect road conditions. MDOT also desired a system that could assist in asset tracking and speed compliance reporting. MDOT executive management expressed a desire to investigate AVL/GPS systems in early 2013 and requested operations and maintenance staff to review available system options. The MDOT Division of Operations Field Services leadership was responsible for initiating this project.

4.2 Factors Considered

MDOT desired to implement a system that could help measures positive impacts on labor efficiency, material usage, fuel consumption, and asset management. To gain a better understanding of the potential benefits of an AVL/GPS system on winter maintenance operations, MDOT surveyed other states using the technologies through the Clear Roads program and the Maintenance Decision Support System (MDSS) Pooled Fund Study. MDOT realized that a comprehensive solution that marries AVL technology and MDSS services would deliver the desired results for effective management of its fleet and winter operations.

One of the lessons gathered by MDOT was related to the challenges of maintaining separate contracts for both an AVL/GPS system and an MDSS provider, in addition to other contracts for cellular equipment, could create issues with the coordination required between multiple contractors. Based on this finding along with the desired aggressive implementation schedule, MDOT proceeded with the procurement of a single contractor that would be responsible and accountable for the management of both the AVL/GPS system and the MDSS system operations.

MDOT decided that it was desirable to allow for the selected AVL/GPS system vendor to store all data collected by the system, though MDOT would still retain ownership of all the data collected by the system. This arrangement would reduce the amount of coordination required with MDOT internal IT staff and also help expedite the deployment of the system prior to the 2013-2014 winter maintenance season.

5. Data Collection and Management

5.1 Data Collection

All AVL system data communicated from MDOT vehicles is stored on a server managed by Parsons as the AVL system provider. AVL system data is reported from vehicles to the central server once every minute. The data is available for review by MDOT staff through the AVL software interface. Data collected by the AVL system include:

- Vehicle location, speed and direction
- Air and pavement temperatures
- Plow/blade positions
- Wing plow and tow plow usage
- Types of material applied
- Material application rate and amount used
- Engine diagnostic data
- Dash cam images

MDOT chose to have the AVL vendor store the data on an off-site server due to challenges associated with MDOT IT security. MDOT still owns the data and can obtain it at any time. All data were warehoused since the beginning and were saved for the lift of the contract. Only 12-month data was kept as “active” and the remaining data was archived but still accessible. The AVL system data is shared with and can be accessed by MDOT Transportation Operations Centers (TOCs) and MDOT ITS Data Use Analysis and Processing (DUAP) program. The data is also fed into the MDSS. The MDSS accesses the AVL data directly through Parsons’ server and uses the data along with other weather information to generate weather forecasts and treatment recommendations.

MDOT also extracts raw data directly from the AVL software interface for separate analyses and internally developed reports on statewide and regional performance related to snow plow operations.

5.2 Data Accuracy

MDOT staff have gained experience with the use of the AVL/GPS software interface and the MDSS software interface since the beginning of the system installation in the 2013-2014 winter season. In general, MDOT was satisfied with the accuracy of the vehicle location tracking feature. MDOT noted that the accuracy of material usage would be closely related to how snow plow drivers use the system in the field.

For example, while the MDSS software can present an estimated amount of material applied by snow plow drivers, the measure of material applied is drawn from the operation of the spreader controller, regardless of whether material is being applied. Snow plow drivers may allow the vehicle spreader controller to operate throughout an entire driver shift to keep the vehicle augur from freezing up in cold temperatures, which results in a higher amount of material usage reported through the software.

In other instances, snow plow drivers are required to report the observed weather and pavement conditions using the in-vehicle touch screen display as part of the AVL/GPS system. Drivers' inputs, along with other AVL data, are valuable data that are used by the MDSS to generate treatment recommendations. A lack of reported inputs from snow plow drivers through the AVL system can lead to less accurate treatment recommendations provided to drivers through the AVL/GPS system.

Continued training of MDOT snow plow drivers on proper use of the system can lead to increased accuracies of the material usage reported, as well as increases in the accuracy of the treatment recommendations.

5.3 Staffing and Resources

Staffing and resources needed for data collection and management were not an issue with MDOT since all data were stored and managed by Parsons and Iteris. MDOT maintenance supervisors use the software interfaces to access the data to assist in winter maintenance as part of their regular tasks. MDOT staff continue working with Parsons and Iteris to enhance the software interface features and capabilities.

One of the next steps that MDOT envisions with the MDSS software interface is the creation of a Reports module that would be able to run the same kind of reports that MDOT runs through the AVL software package. This will reduce the amount of MDOT staff time spent running two separate software packages and improve the efficiency of MDOT maintenance supervisors in reviewing past winter weather events. MDOT also desires to implement automated reports within the MDSS software package to reduce the amount of time spent completing paperwork that snow plow drivers at the end of their respective shifts.

5.4 System Data Usage

MDOT staff use the data from the AVL system and the MDSS for monitoring vehicle locations and road weather conditions, staffing and resources allocation and planning, material usage tracking, performance monitoring and reporting, research, among others. Measuring the efficiency of salting operations is one key measure that MDOT produces statewide by region and by County where AVL system data is installed. Figures 14 and 15 show a statewide summary and the Grand Region summary for reference on FY 2017 direct force salt efficiency data. The key salt effectiveness measure MDOT has learned through previous research is that salt scatters outside the travel lanes as snow plows travel in excess of 25 MPH while applying salt to the travel lanes.

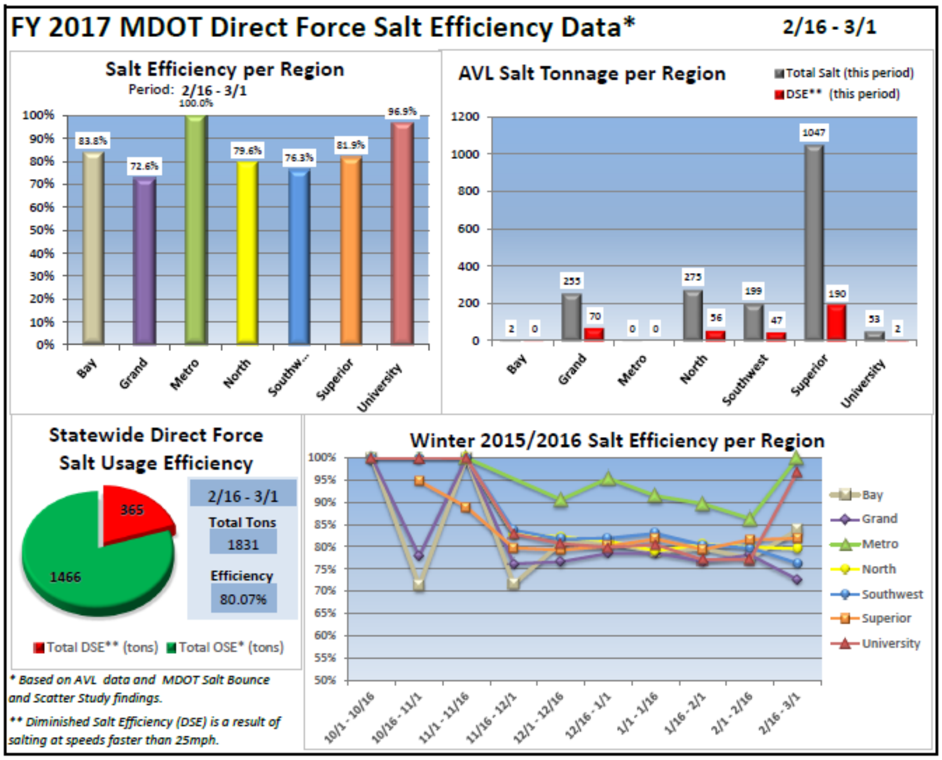


Figure 14. MDOT Salt Efficiency Data Statewide by Region with Direct Forces

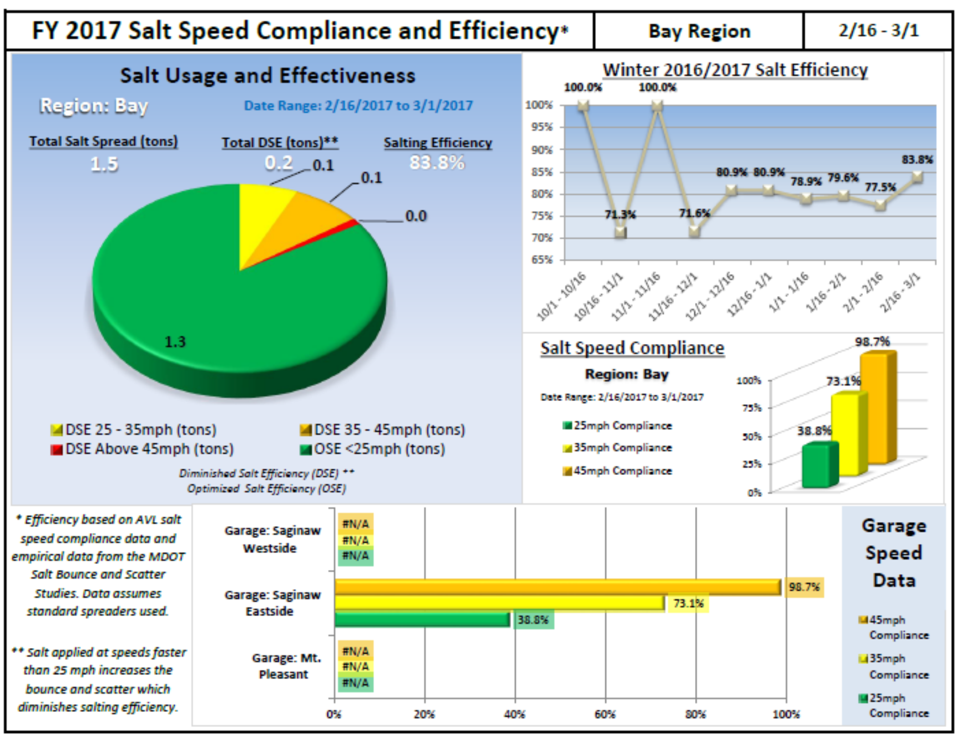


Figure 15. Grand Region Salt Efficiency Data and Speed Compliance Data

A summary of other ways in which MDOT utilizes the system data is presented below.

- The AVL system is used to track vehicle engine hours to schedule preventive maintenance for winter maintenance trucks.
- MDOT uses the AVL data to identify issues with system malfunctions, such as using missing data to investigate if antenna is not working properly or MDC is malfunctioning.
- The AVL data is used to track snow plow vehicle speed and location. Vehicle location information is also shared on the MiDrive website to the public.
- The AVL data is used to record types of material applied and application rates. MDOT supervisors use the AVL software to generate material usage reports.
- The AVL data is used for salting speed compliance reporting.
- The system data is also used for tracking blade usage.
- MDOT supervisors use the data for operational and resource planning according to the MDSS weather forecasts and treatment recommendations. MDOT supervisors monitor weather events, determine the optimal time to call in snow plow drivers, and determine the best course of material application.
- MDOT also uses the data for post-storm reviews. It allows MDOT to review the effectiveness of roadway maintenance activities and identify lessons learned, areas for improvement and best practice.
- Dash cam images are used by supervisors to view the conditions of the roadway or corridors as experienced by the snow plow driver.
- MDOT also uses the data for research. For example, MDOT was able to use the system data to conduct a research project to determine which speed was optimal for spreading materials such as salt, brine, sand, and other de-icing chemicals.
- System data are shared with MDOT TOCs. TOCs use the near real-time operational data from snow plows to observe roadway conditions and improve incident response.

Figures 16 and 17 on the following page present a statewide summary for FY 2017 on MDOT County and Garage winter material usage, where a FY17 year-to-date (YTD) measure of salt usage is compared against a 5-year average of salt usage. The measures allow readers to compare how MDOT regions are performing with respect to each other and to their respective 5-year averages.

Figures 18 and 19 present a similar type of summary for the MDOT Grand Region for FY 2017. Figure 19 presents at a more detailed level as how each County and Garage within the MDOT Grand Region performed with respect to their 5-year average.

Those reports illustrate how MDOT uses data gathered from the AVL / GPS system to monitor and report performance measures on material usage and efficiency across multiple regions and counties over time.

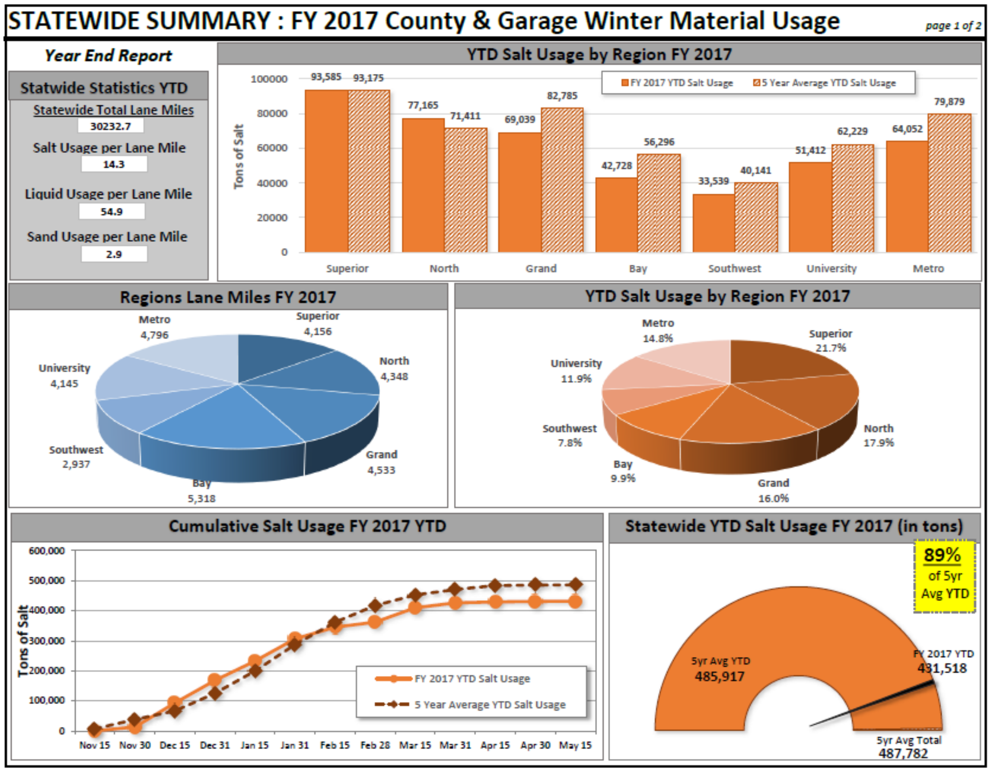


Figure 16. MDOT Statewide Reports of County and Garage Material Usage

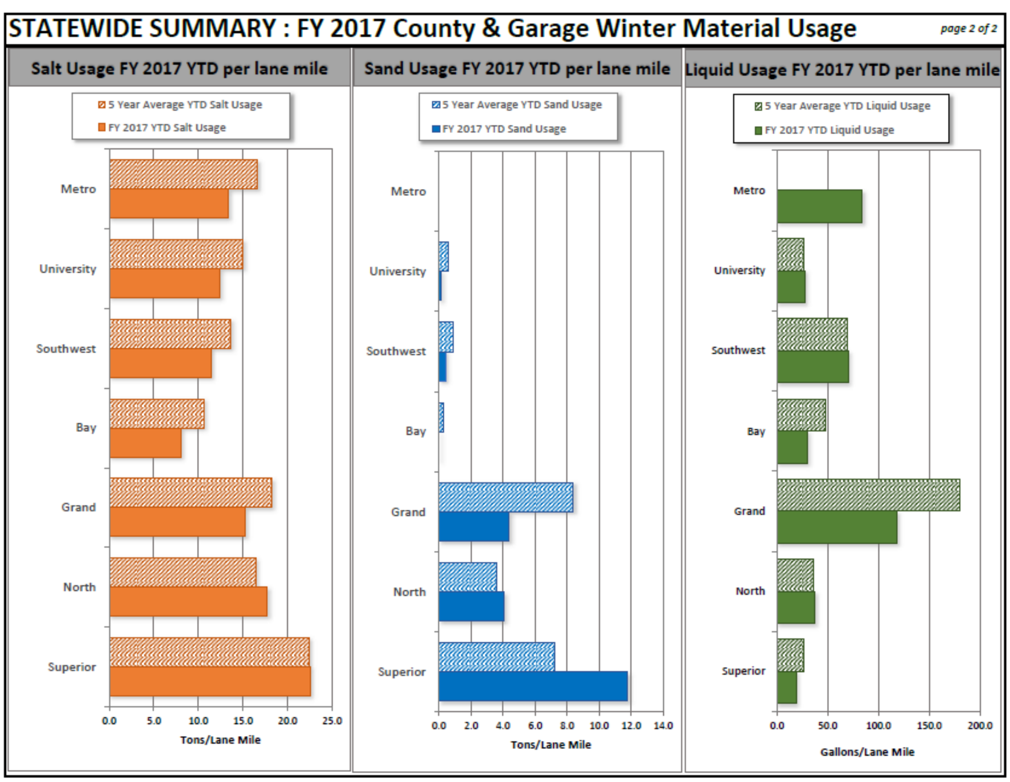


Figure 17. Detailed Material Usage Reports for MDOT Counties and Garages

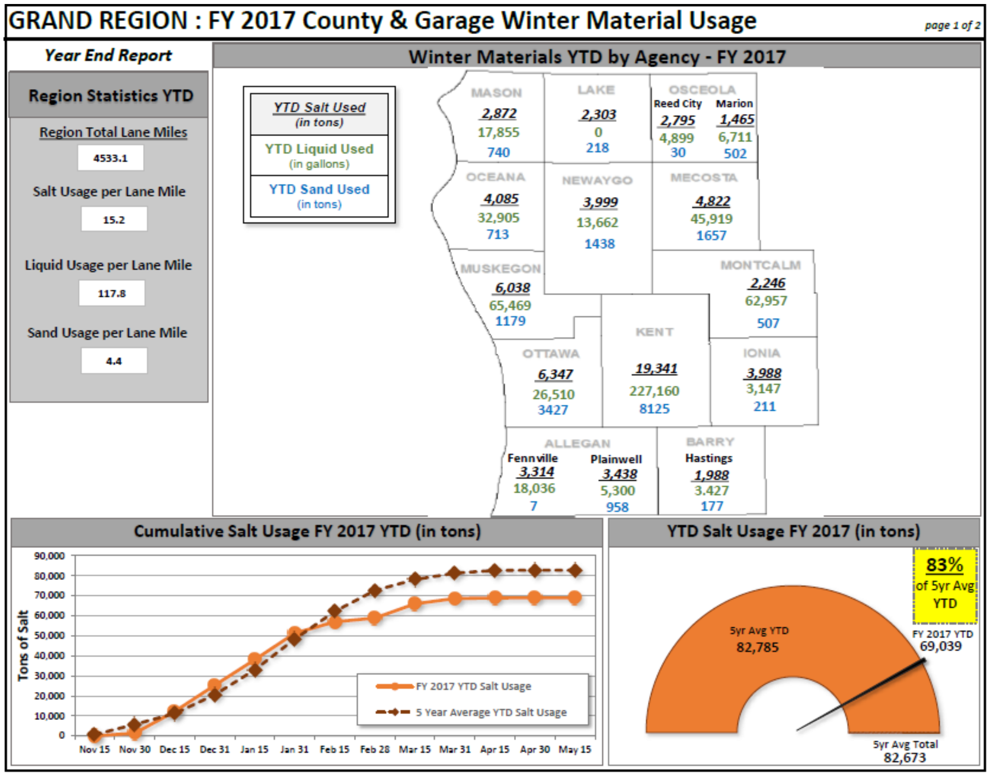


Figure 18. MDOT Grand Region County and Garage Material Usage

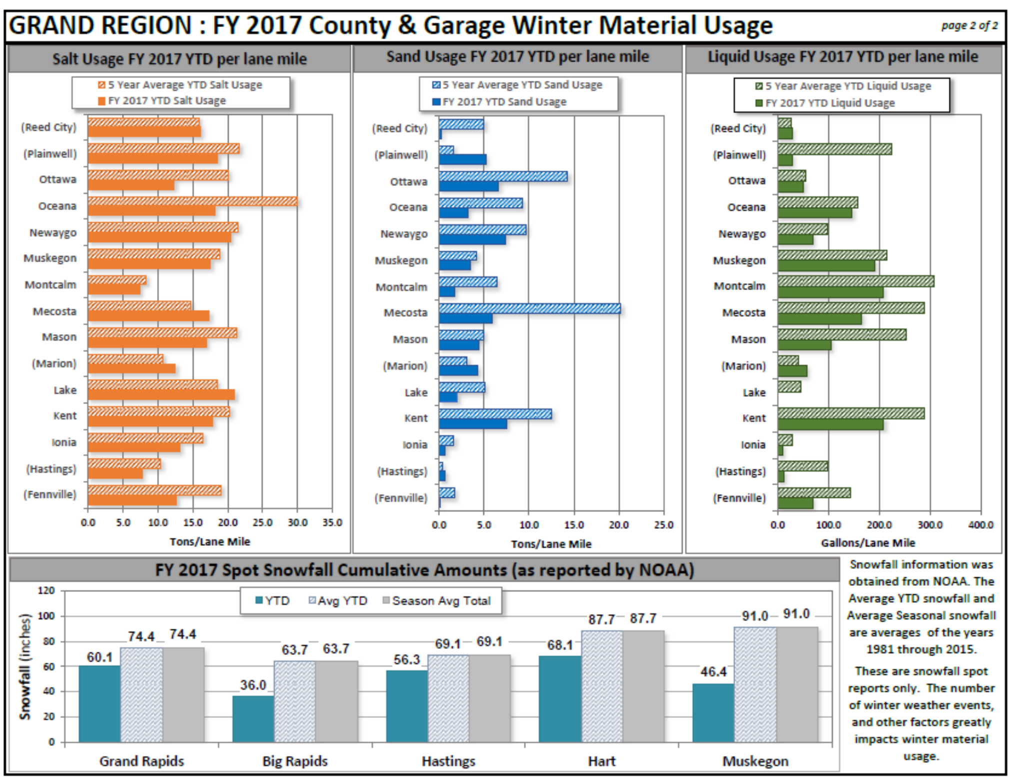


Figure 19. MDOT Grand Region Detailed Material Usage Reports for MDOT Counties and Garages

5.5 Agency Policy and Agreements for Data Sharing

Snow plow locations reported by the AVL/GPS system are shared with the public-facing MiDrive traffic information website that presents traffic and roadway information with the general public. It was noted that there is a small lag of about three to five minutes of when vehicle locations are reported to the general public. MDOT cited public transparency was a key reason for sharing the snow plow locations with the public.

MDOT shared the system data with its TOCs for traffic operations and management purposes. The system data was not shared with other agencies outside of MDOT. However, MDOT has provided MDSS access and training to their contract Counties as a partnering effort. Counties can use the MDSS web interface to obtain location specific weather information and can see MDOT trucks and routes information that may border their maintenance areas. Some counties expressed interest in adding MDSS maintenance forecast routes in County maintained areas. MDOT is current exploring the possibility of this expansion.

6. System Implementation Process

6.1 Implementation Steps

Through initial research and survey of other AVL and MDSS users, MDOT noted many agencies administered separate contracts for AVL implementation and MDSS services. In some cases, agencies also managed separate contracts for cellular communications and data storage and management. Administering multiple contracts and vendors requires more agency staff time and takes away staff attention in efficiently managing the overall project. As such, MDOT management determined that the best approach to procure the system is to use a single all-encompassing contract.

MDOT released an RFP in spring of 2013 and requested a single point of contact from a Contractor that would be responsible for implementing an AVL system, the MDSS services, communications, data storage and management and system integration, as a means of ensuring accountability in delivering a fully integrated system by the selected Contractor.

The RFP included:

- AVL equipment and services for MDOT winter maintenance trucks
- AVL equipment for MDOT’s light fleet
- Communication services
- Data storage and management
- Statewide MDSS services
- Training to MDOT staff

MDOT expressed its desire for the integration of the AVL system with other equipment and technology on the winter maintenance vehicles from the beginning of the contract start date and allowed the Contractor to determine the most optimal plan for delivering the integration for MDOT winter maintenance operations. Through frequent meetings and communication with the Contractor and its project team, MDOT achieved the desired outcome of implementing the system prior to the 2013-2014 winter season.

MDOT staff performed the installation of AVL/GPS hardware on as many MDOT vehicles prior to the 2013-2014 winter season as possible. Training was provided from the vendor on installation procedures to be followed by MDOT vehicle mechanics.

Training on the system functions and operations was provided by Parsons during initial system installation. Continued training sessions, both formal and informal, were provided annually. The MDSS vendor also provided in-person training to MDOT staff on the use of the MDSS system interface.

6.2 Procurement Methods and Process

Prior to issuing an RFP for the project, MDOT consulted with other state DOTs through the Clear Roads pooled fund group to survey other states and discuss best practices for the implementation of this project. AVL/GPS and MDSS system requirements were gathered from other states that had recently gone through a procurement process for similar systems. MDOT reviewed the AVL/GPS and MDSS system requirements from other agencies prior to developing MDOT’s requirements in the RFP package.

The RFP was competitively bid utilizing the MDOT best value procurement process. Proposals were reviewed by a Joint Evaluation Committee (JEC), and ratings were given based on requirements outlined in the RFP. The final award determination was based on a formula that included the committee’s ratings on the technical portion of the proposal as well as the pricing.

The best value selection method helped MDOT select a vendor that could meet the overall technical requirements of the project based on past project experience, as well as provide the project management services to work to meet the proposed aggressive schedule of the project.

6.3 Procurement Documents

The AVL/GPS system requirements from MDOT’s RFP package are included in Appendix B, and the MDSS system requirements can be found in Appendix C.

7. System Benefits and Costs

7.1 Implementation Costs

A summary of the AVL equipment costs provided to MDOT in 2013 are provided in Table 2. Unit costs presented in the table pertain only to MDOT Winter Maintenance Trucks (WMTs). The WMT AVL package provided by the contractor included the AVL hardware in addition to other sensors and equipment installed on the vehicles.

Given that MDOT was requesting a single contractor to be accountable for the combination of AVL/GPS system integration with the MDSS software package, MDOT also requested project management costs in addition to installation, website training, and other vendor services. The total cost of the services over the span of the three year life span of the contract entered into by MDOT in 2013 is presented in Table 2. A separate cost estimate was also provided for non-WMT vehicles, which represented other MDOT-owned vehicles. Those costs are not included in Table 2.

Table 2. Hardware, Installation, and Training Costs of MDOT AVL/GPS System

Items	Quantity	Unit Cost	Total Cost
Hardware			
WMT AVL Package Including: AVL Hardware Material Flow Meter Solid RoadWatch Temperature Sensor Gate Sensor Hydraulic Meter Sensor Plow Blade Sensor	338 vehicles	$4250.49	$1,436,666.84
Installation, Training and Vendor Services			
Project Management	3 year contract items bid by Contractor		$341,833.32
Installation / Equipment Maintenance			$55,900
Annual Website Usage Training			$19,105.86
Annual Technical Support			$178,616
Annual Data Storage			$249,429.99
Annual AVL Website Management			$79,373.00
Sum of WMT AVL Hardware, Installation, and Training			**$2,360,925.01**

7.2 Costs for operations and maintenance

The monthly cellular service costs for the various vehicle types are presented in Table 3. Note that the prices in Table 3 were requested for the three year life span of the project. For each year of the contract, MDOT requested monthly cellular service costs for 6 months of high data consumption during the winter period, and another 6 months of low data consumption during the summer period.

Table 3. Monthly Service Charges for First Year of System Operations

Items	Quantity	Unit Cost	Total Cost
Service Charges			
High Data Consumption 6-Month Period	338 WMT trucks * 6 months * 3 years	$49.50 / month	$301,158.00 / 3 years total
Low Data Consumption 6-Month Period	338 WMT trucks * 6 months * 3 years	$22.00 / month	$133,848.00 / 3 years total
Sum of Monthly Service Charges for Three Year Contract			**$435,006.00**

7.3 Benefits

MDOT noted that prior to the implementation of the AVL/GPS and MDSS systems, their approach to winter maintenance was completely reactive. Once a winter storm would arrive, maintenance crews would be sent out to and snow plow operators would apply roadway chemicals at their discretion on where and when it should be applied.

Since the system installation, MDOT's approach to winter maintenance is much more proactive, and snow plow operators are now spreading a correct amount of de-icing material at the correct time making the agency much more efficient and effective. By combining current fleet operations measured through the AVL/GPS system with an improved knowledge of future weather and roadway conditions from the MDSS system, maintenance crews are better targeting employee efforts, reducing material application, and decreasing equipment usage. Additionally, MDOT has been more proactive to changing weather to get ahead of snow covered or icy conditions to provide the traveling public with a safer, better level of service.

8. System Issues and Challenges

8.1 Institutional Issues

MDOT staff noted that the AVL/GPS system and MDSS implementation had overall support from MDOT executive management, and the arrangement of one Contractor being accountable for the entire project expedited the overall procurement and installation of the system.

However, due to the aggressive schedule desired for system installation, a desired level of outreach to users of the systems could not be performed.

MDOT noted that the goal of having all WMT AVL hardware units ordered, installed and reporting data by January 2014 was not met. The timing of AVL hardware installations coincided with the start of the fall and winter season, when MDOT vehicle mechanics were pressured by the daily task of keeping the WMTs on the road. As a result, the AVL equipment installations became a lower priority to MDOT mechanics once winter started, and keeping the WMTs operational during the continuous storm events of the 2013-2014 proved to be a challenge.

8.2 Technology Issues

MDOT did not experience many technical issues with the technology. MDOT staff noted one issue was the MDC would not start under low voltage. The MDC would turn on briefly but then shut off and would not turn on again. MDOT suspected the issue could be due to wiring and has been working with Parsons to identify the causes and solutions. MDOT noted specifying power supply requirements in the RFP would likely alleviate the issue.

MDOT WMTs were equipped with DICKEY-john spreader controllers. The integration of the spreader controllers with the AVL system was Parsons' responsibility as defined in the contract. DICKEY-john was a subcontractor to Parsons for the project. As such, the two vendors worked together to resolve any integration issues.

8.3 Procurement and Implementation Issues

8.3.1 Procurement Issues

MDOT staff noted that the arrangement of one Contractor being accountable for the entire project expedited the overall procurement and installation of the system. Selecting the right vendor partner is crucial, and a "Best Value" selection helped MDOT select a vendor that could work to meet the aggressive proposed implementation schedule and overall technical requirements of the project.

8.3.2 Implementation Issues

MDOT desired to have the AVL system installed prior to the start of the 2013-2014 winter season. The contract with Parsons for the AVL system installation was executed in late September 2013, at the beginning of the fall season when MDOT vehicle mechanics were preparing MDOT snow plows for the coming winter season. As noted earlier, Parsons provided training and MDOT mechanics handled the AVL equipment installations on all MDOT WMTs. The aggressive schedule desired by MDOT could not be met, as MDOT vehicle mechanics were pressured by the daily task of keeping the WMTs on the road. As a result, the AVL equipment installations became a lower priority to MDOT mechanics once winter started, and keeping the WMTs operational during the continuous storm events of the 2013-2014 proved to be a challenge.

MDOT indicated that having agency mechanics install the vendor- supplied equipment creates an atmosphere of ownership in the system among many of the mechanics. It also gave them firsthand knowledge of how the equipment was installed and how it functions and interacts with other vehicle equipment. This proved useful for future equipment maintenance and replacement.

MDOT also encountered a few installation issues. The AVL hardware (MDC) on the vehicle was initially mounted in the center console area where it was susceptible to damage from liquid spills due to its proximity to cup holders. MDOT relocated the MDC behind passenger seat to resolve the issue. The MDC was initially installed with cable connector panel facing down and near the floor, as shown in Figure 20. MDOT quickly realized that it was challenge to access the cable connections with such installation. Subsequently the MDC installation was adjusted to have the connector panel facing sideway to allow easy access.

Figure 20. AVL Hardware Installation: Connector Panel Facing Down (right) and Connector Panel Facing Sideway (left)

Another installation related issue was the wiring for the cellular / GPS antennae. Initially MDOT mechanics didn't want to drill an additional hole through the vehicle roof. As such, mechanics run the antenna cables through an existing hole for one of the side markers on the roof as illustrated in Figure 21. MDOT found out that the cables were susceptible to damage due to such installations. Subsequently mechanics took corrected actions by drilling a hole through the vehicle roof and re-routed the cables.

Figure 21. Improper Installation of Cellular/GPS Antenna Cables

MDOT also noted that different types of trucks and ages of trucks may require different cabling, connectors, equipment mounting locations, etc. for installation. The variations in installation could not be captured fully in the training for mechanics. Mechanics needed to be savvy and flexible to ensure needed parts were ordered.

Some snow plow drivers expressed a dislike of the additional monitor in the trucks, which they felt was too much to monitor given the high amount of other equipment already in the truck. Some drivers also felt that they could use their smartphones to achieve some of the same functionality, namely the weather radar images and weather tracking.

Some drivers also reported the brightness and color contrast of the monitors, especially in low light conditions. MDOT expressed the desire to have an automatic dimming feature for monitors going forward to ease the strain on drivers.

8.4 Operations and Maintenance Issues

MDOT staff noted that the process of equipment installation and training of staff on equipment installation was condensed into a short amount of time in order to get system operational prior to the 2013-2014 winter weather season. Additional time to train vehicle mechanics on equipment installation and garage supervisors on how to use the software would likely have reduced the number of issues that were encountered.

MDOT noted one issue related to the system operations. Battery draw was a concern as there were many devices drawing power from the same battery. MDOT installed a battery shut off switch to resolve the concern.

No maintenance issues were experienced by MDOT. On rare occasions when the AVL hardware or components failed, defected items were repaired or replaced under warranty.

9. Lessons Learned

The following lessons learned are offered based on the MDOT case study.

- Leveraging other agencies' experience in RFP and requirements development, procurement, installation and operations is extremely valuable.
- Specifications of the system in the RFP should not be too specific to limit agency's options and flexibility.
- Using an all-encompassing contract to hire one single vendor to be responsible for delivering a desired solution reduces agency staff resources required and helps integration of multiple systems; although this approach might increase the overall project cost.
- Support from executive management made procurement and roll-out quicker.
- Outreach to users, especially prior to installation, helped reduce resistance and promote buy-in.
- An aggressive installation schedule may hinder agency's ability and opportunity to perform desired level of user outreach.
- Adequate training is key to buy-in and successful operation. Having tech-savvy staff performing outreach, conveying key messages and supporting installation and operations helps alleviate concerns and promote buy-in.
- Different types of trucks and ages of trucks may require different cabling, connectors, mounting locations, etc. for installation.
- Ease for access and maintenance should be considered when selecting the mounting location for the AVL hardware. In addition, the AVL hardware should be located to minimize potential damage due to liquid, tools or other equipment.
- Battery draw can be a concern as there were many devices drawing power from the same battery. Installation of a battery shut off switch could be a solution. Understanding of the power requirements and consumption of individual devices helps better identify the problems and allows agencies to define and include specifications for power supply and consumption in RFPs.
- Timing of the AVL system installation should be arranged to avoid conflicting with winter seasons when the availability of winter maintenance vehicles may be limited.

Appendix A Survey Response

Name	Title	Agency	Phone	Email
Gregory Perry	**Roadway Ops Engineer**	**Michigan DOT**	**517-322-3394**	**perryg1@michigan.gov**
AVL/GPS System				
1.Are you currently using an AVL/GPS system to automatically collect data for your winter maintenance operations?			Yes	
2.Does your agency have plans to implement or expand AVL/GPS technologies on your winter maintenance vehicles in future years?			Yes	
If yes, please describe the anticipated implementation or expansion:			Expand as we update our fleet	
3.Approximately how many vehicles are in your winter maintenance fleet?			340	
4.How many of your winter maintenance vehicles are equipped with AVL/GPS technology?			321	
5.Who is your contracted AVL / GPS vendor?			Parsons	
6.What modem / GPS brand(s) does your agency utilize?			MDC-004	
7. Who performed the installation of your AVL/GPS system? Was it the system vendor or DOT agency staff?			Both	
8. Who is maintaining the AVL/GPS system after installation? Is there a maintenance contract with the system vendor, or is it maintained in house by DOT agency staff?			DOT Agency Staff	
9.Were there any issues with the installation of your AVL/GPS system?			No	
Integration				
10.What auxiliary equipment and sensors are installed on the vehicles and integrated with your AVL system? Please check all that may apply.				
Spreader controller			Yes	
Plow controller			No	
Plow position sensor			Yes	
Mobile data terminal/computer			No	
Pavement temperature sensor			No	
Air temperature sensor			No	
Humidity Sensor			No	
Dashcam			Yes	
Other (describe below)			No	
If you indicated "Other" in the question above, please describe below.				
11.Have you experienced difficulty integrating above equipment or sensors into your AVL/GPS system? If so, please describe.			No	
12.What brand(s) of spreader controller does your agency use?			Dickijohn	
Data Management				

Name	Title	Agency	Phone	Email
Gregory Perry	Roadway Ops Engineer	Michigan DOT	517-322-3394	perryg1@michigan.gov

13.What types of data other than vehicle location are being captured with your AVL system? What is the data capture frequency? Please check all that may apply	
Plow position	Less than 5 min.
Material application rate	Less than 5 min.
Type of material applied	Less than 5 min.
Mobile data terminal messages	Not captured
Pavement temperature	Less than 5 min.
Air temperature	Less than 5 min.
Humidity	Not captured
Surface friction	Not captured
Dashcam	Less than 5 min.
Engine diagnostics	Less than 5 min.
Other, please describe below	Not captured
If you indicated "Other" above, please describe below.	
14.Where does the AVL system data reside after it is transmitted from the vehicles?	Parsons plat form
15.Do you use the AVL system data to perform any of the following items? Please check all that may apply.	
Vehicle location tracking / fleet monitoring	Yes
Route/operational planning and optimization	No
Material usage tracking and analysis	Yes
Treatment recommendations	No
Providing data to a maintenance decision support system (MDSS)	No
Operational analysis, evaluation and performance reporting	Yes
Collection of vehicle diagnostic data	Yes
Sharing of vehicle location through agency traveler information webpage	Yes
Road weather condition reporting	No
Staffing analysis and management	No
Other, please describe	No
16.Does your agency share data collected through the AVL system internally with other divisions or offices within the department?	Yes
If yes, what do those divisions/offices use the data for (e.g., operational analysis, planning, performance reporting, budgeting, etc.)?	ITS department
17.Does your agency share AVL system data externally with other public agencies?	No
18.Does your agency share AVL system data externally with any private agencies, such as private weather service providers?	Yes
If yes, please describe what data is being shared with these other agencies.	Location, material usage, photos
19.Does your agency share AVL system data with the general public?	Yes
If yes, please describe what AVL system data is being shared with the general public.	Location and photos

Name	Title	Agency	Phone	Email
Gregory Perry	**Roadway Ops Engineer**	**Michigan DOT**	**517-322-3394**	**perryg1@michigan.gov**

Communications	
20.What type of communications does your AVL/GPS system use to transfer data? Please check all that apply.	Cellular network
21.How would you rate the coverage of your communications system?	Covers all of maintenance areas
Operational and Procurement Aspects	
22.Do you have a distributed approach to tracking vehicle locations (i.e. by district or geographic boundaries)? Or is there a centralized method of tracking all vehicles within the agency boundaries? Or do you use a mix of both approaches?	Distributed approach
23.Is your agency's AVL system equipment provided by a single vendor or multiple vendors?	Single vendor
24.Does your agency utilize a web-based interface accessible over the internet to access operational information?	Yes
If yes, how is the data that can be extracted from the interface utilized to improve upon winter maintenance operations?	monitors material usage and labor
25.Does your agency extract data from the AVL / GPS system and / or web-based interface for separate analyses to improve upon winter maintenance operations after winter weather events?	Yes
If yes, please describe how the data is utilized by your agency.	Only if there was a sever crash, or involving several vehicles
26.What was the procurement process used for your AVL/GPS system (i.e. Request for Proposals (RFP), Invitation for Bids (IFB))?	Request for Proposals (RFP)
Was a demonstration of the system included as part of the evaluation of respondents?	No
27. Does your agency move your AVL/GPS vehicle units to different trucks or equipment for use during summer maintenance operations?	No
Costs and Benefits	
28.Do you have cost information associated with your AVL system?	Yes
29.What cost information would you be able to provide?	
AVL equipment costs	No
Installation & integration costs	No
Costs associated with on-going operations (staffing, communications, software licensing,	No
Maintenance costs	No
Other costs, please describe	No
30.Has there been any formal or informal benefits assessment or benefit-cost analysis performed on your AVL system and/or other technology for winter maintenance operations?	No

Name	Title	Agency	Phone	Email
Gregory Perry	Roadway Ops Engineer	Michigan DOT	517-322-3394	perryg1@michigan.gov

Deployment Experience

31.Please share any general lessons learned in the deployment of AVL/GPS technologies below that would assist agencies considering a future deployment of these technologies.	Had issues with the non-user friendly vendor website and hydraulic sensors
32.May we contact you with follow-up questions about your system(s)?	Yes

Appendix B MDOT AVL/GPS System Requirements

Attachment B:
MDOT AVL-GPS System Requirements
Requirements listed below are minimum specifications for the AVL-GPS System and Services

Category 1	Equipment
	General
B.1.1	Vehicle Mounted Hardware – All equipment must be solid state with no moving parts such as fans and all communication hardware shall be fully integrated into the housing with no openings. The unit will be enclosed by a ruggedized case.
B.1.2	All equipment must be "off the shelf" and currently used by other agencies/ groups for AVL.
B.1.3	All equipment shall be uniform within the two asset classifications (WMT and Non-WMT) and must be operational across all vehicle types.
B.1.4	System Data Storage - The system must support at least 1 GB flash memory for storage of data over extended periods of power loss or 48 hours of observations whichever is greater. (This allows for storing all readings until 802.11 b/g or GPRS coverage is re-established then transmitting the stored data to provide an updated history of the vehicle.)
B.1.5	Delayed Data Transmission - The system must provide *Store and Forward* capabilities capable of storing over 1 GB of information while out of cellular communications coverage and automatically forwarding the same when back in coverage. (System collects vehicle activity data and geo-stamp data and stores onboard until data can be securely transmitted to provide a detailed historical record of activity while in the field.)
B.1.6	Power Loss - The system must provide ability to detect and report previous power loss if unit is disconnected then reconnected. (This reports if someone was to disable the system during their shift whether inadvertent or intentional.)
B.1.7	Power – The unit shall run off the vehicles power system.
B.1.8	Upon vehicle ignition, the vehicle will automatically report to the system. No operator interface will be necessary to begin transmitting position and sensor data. All information on vehicle status shall be stored and accessible on through an online database
B.1.9	AVL control unit must feature a power management feature or "sleep mode" and/or "Charge guard". This is to ensure that the vehicle battery is not discharged, after the vehicle is turned off. The current draw (Amps) of the AVL package must be minimal and allow for vehicles to sit unused for up to 2 months without discharging battery.
B.1.10	Power Surge/Failure – Unit shall have built in protection from low and high voltages.
B.1.11	System Operation - System must meet SAE J1455 environmental specifications and provide +/- 25g shock rating (Provides a ruggedized solution in the high abuse environment that system will be used in.) Operating temperature shall be in the range from -40 F to 140 F and operating humidity up to 95%.
B.1.12	The unit will produce low heat and have a low power consuming processer with a minimum processing speed of 1 Ghz.

B.1.13	GPS unit shall be satellite based GPS with WAAS enhanced accuracy. There will be a 12 parallel channel, Wide Area Augmentation System (WAAS) enabled GPS receiver.
B.1.14	GPS receiver must be accurate to less than 2 meters.
B.1.15	GPS output interval shall be programmable as determined by the Department with collection intervals at least once every second. The ability to remotely configure collection intervals on GPS units shall be available.
B.1.16	Remote Updates - System must support over-the-air firmware updates. (This allows for updating the system without the need to physically connect to each unit to manually update them.)
B.1.17	Antenna – The antenna shall be internal to the system.
B.1.18	Universal Time – System will synchronize both the unit and database to the universal time clock and time stamp all data collected.
B.1.19	System Operation – The system shall transmit from all integrated sensors simultaneously with the timestamp.
B.1.20	All connections between sensors and equipment must be hard-wire ruggedized connections.
B.1.21	System must not interfere with Original Equipment Manufacturer (OEM) electronics
B.1.22	Sensor Output – Capable of sending sensor data in its original format for data integrity and/or processing controller, camera and/or other data for in vehicle display and other purposes.
B.1.23	The system must be able to interface to on-board discrete sensor inputs and 3rd party data logging systems simultaneously.
B.1.24	The AVL control unit must be able to communicate with on-board equipment sensors installed on the vehicle to report their present status and changes to their status in real-time. The sensors, such as proximity switches, infrared, magnetic read switches, micro limit switches or equivalent must be able to communicate their present status to the equipment with necessary cabling connected to onboard equipment when required.
B.1.25	The AVL system shall be programmable in common full programming language such as JAVA, to accept input from sensors provided by the contractor, or third party.
B.1.26	Additional Software – The system will be capable of carrying additional VPN software at the department's discretion.
B.1.27	Troubleshooting – the system shall have self diagnostic capabilities to facilitate troubleshooting and maintenance activities.
B.1.28	Warranty – The system shall be warranted for a two year period following installation and final acceptance of each package as defined in the RFP
B.1.29	The system must allow for future enhancements that can allow for easy configuration, expansion and scalability. (examples include: additional sensors, control units, hardware)
B.1.30	System Transfer – The AVL system must allow for transferal to replacement vehicles with minimal reprogramming and downtime. If a memory chip is used, there must be easy access to it should its replacement or reprogramming be necessary.
	Non-WMT Package Only
B.1.31	*Non-WMT Package AVL Control Unit*: Simple Tracking unit must at a minimum be able to interface to two (2) inputs.

	WMT Package Only
B.1.32	*WMT Package AVL Control Unit (with on-board systems integration functionality)*: AVL control unit must at a minimum be able to interface at least 16 digital sensor inputs, four (4) analog to digital input, four (4) dedicated outputs, two (2) RS232 communication Ports, two (2) USB Ports, and an Ethernet port.
B.1.33	System Display Screen – Internally configured to support an in vehicle display screen, whether screen is used or not.
B.1.34	The display screen shall be sized a minimum of 6 x 8 inches.
B.1.35	In cab display system controls- Any operator controls for the display screen must only be allowed to function when the vehicle is stopped or traveling less than 3 mph.
B.1.36	The AVL system shall include sensors able to collect data from the spreader controller or other supplemental equipment for the following data:
a.	Plow Sensor (front plow, wing, underbody, tow plow)
b.	Pavement Temperature and Ambient Sensor
c.	Auger Feedback Sensor
d.	Gate Sensor
e.	Hydraulic Flow Meter Sensor
f.	Material Flow Meter Sensor (to monitor if material is dispensing from WMT and to verify spreader controller).
B.1.37	For all salt spreader controls, the data should be collected, stored and reported whenever a change to any of the following fields occurs: solid material type (eg salt/sand), solid material spread rate, solid material spread width, gate setting, blast on/off, pause on/off, liquid material spread rate, prewet on/off, and error status – depending on the availability for the particular spreader controller.
B.1.38	The system shall be capable of interfacing to the vehicle's on-board computer to collect engine data available via OBDII and the SAE standard J1708/1587, CANBUS, and J1939 networks. Such information may include but not be limited to: • Engine Speed; • RPM; • Coolant Temperature; • Fuel Level; • Trip Fuel; • Oil Pressure; and • Battery Voltage.
B.1.39	If Engine Hours and Odometer values are unavailable from the vehicle's on-board computer the system must be able to calculate virtual Odometer and Engine Hours based on the reporting of the vehicle and GPS distance. However, The system must provide user-configurable odometer and hour meter synching to the vehicle's actual odometer and hour meter. On board odometer and hour meter takes precedence over any virtual data.
B.1.40	Spreader Controller Integration – The system must integrate with Dickey John Control Point and ICS2000 controllers and the AVL modem. Any modification to the system is at the expense of the contractor.

B.1.41	The system shall allow for an optional front mount camera, to be powered off of the AVL.
Category 2	**Communications**
B.2.1	Communications – The communications technology to be used for transmitting data must be dual mode – 802.11 b/g and GSM/GPRS. System must include all necessary hardware items, processors, antennas, etc. (This provides the flexibility to use either 802.11 b/g wireless or GPRS to do automatic data downloads if necessary.)
B.2.2	Data Transfer – Unit shall transmit data using the TCP/IP protocol. All services used shall be RFC compliant.
B.2.3	Cellular communications – The unit shall be able to operate on multiple major cellular carriers and or private networks, in different parts of the state, with the simple replacement of the communications module.
B.2.4	Cellular Coverage - The AVL system must be able to transmit data from at least 90% of the MDOT roadway network across the state.
B.2.5	Non-WMT Communications– The Cellular data plan must allow for data transmittal to the mapping website at least once per day for non-WMTs from January 1st thru December 31st
B.2.6	WMT Communications– The Cellular data plan must allow for data transmittal to the mapping website at least once per day for WMTs during non-winter months, defined as being from April 30th to October 31st. The cellular data plan must allow for data transmittal to the MDSS provider and the mapping website(s) to be at least 60 seconds within real time conditions for WMTs during winter months, which is defined as being from November 1st thru April 30th. The definition of winter, and non-winter months are subject to change by the CCI.
B.2.7	Communications – Capable of using and changing carriers by changing carrier connection card or module without changing or replacing unit or other equipment.
B.2.8	Communications – Capable of migrating to next generation communication technologies with change of connection card or module without changing or replacing unit or other equipment.
B.2.9	Vehicle remote configuration must be web browser based, which is capable of logging into the AVL control unit to: • Set distance and time reporting intervals • Set destinations for data communications • Detect Sensor status changes and expansion of devices
B.2.10	2 way communication capabilities – provide capability to send messages and images to the vehicle as well as receive data and images from the vehicle when 2-way communication equipment is installed in vehicle.
B.2.11	Individual vs. Group/Fleet messaging – When 2 way communication is set up with vehicle it will provide messaging capabilities for one, all or groups of trucks, without use or additional cost of "text messaging".

B.2.12	The data from the equipment to the database shall include the following near real-time as well as recorded historical information, a) Vehicle speed, direction and location, b) Engine on or off, c) Engine idling vs. running time comparisons, d) Time and distance by each monitored sensor, e) Stop time data.
Category 3	**MDSS (also refer to Attachment D-MDSS System Requirements)**
B.3.1	MDSS Integration
a.	In vehicle mobile data collection units with integrated maintenance decision support systems, in accordance with these Specifications – The unit shall be of such design and construction as to comply with the requirement hereinafter stated and any parts or attachments necessary to form a complete, functioning unit must be furnished, whether specifically mention herein or not.
b.	Required NTCIP Compliance – All equipment and software must be compliant with NTCIP standard 1204.
c.	All costs to enable proper communication between the MDSS and weather forecasting provider and the optional in vehicle display screen will be borne by the contractor. The in vehicle display screen shall display local radar, short term weather forecast and recommended maintenance treatment.
d.	The MDSS shall also conform to specifications detailed in Attachment D
B.3.2	a. The Contractor shall demonstrate an understanding of Michigan weather and climatology, as well as a thorough knowledge of winter weather patterns and the variations within the State. b. The Contractor shall demonstrate an understanding of MDOT's trunk line system and its winter maintenance practices. c. The weather forecasting system shall include integrated MDSS functionality to support appropriate road maintenance actions that result in optimal road surface results with efficient use of resources for specific weather conditions. Treatment recommendations shall be provided for each hour of the forecast when indicated by the current and future pavement and weather forecast parameters. d. The system shall support the FHWA Pavement Recommendation Rules of Practice regime as the default treatment recommendations for specific weather situations. It shall also allow users to incorporate their own customized treatment plan recommendations to reflect individual best practices in chemical application, timing, type and rate as well as plowing actions. Users must also be able to select the appropriate route cycle times or times for their routes. Treatment recommendations must be provided for the next 48 hours to indicate required actions prior to, during, and after a storm.
B.3.3	All forecasts provided by the Contractor will become the property of the Department. The Department may, at its discretion, share the forecast with other agencies as appropriate. A unique forecast shall be provided for each localized area/route.
B.3.4	Maintenance Decision Support tools including road treatment recommendations

	will be required November 1st through April 30th, unless otherwise instructed by the CCI
B.3.5	Short-Term Forecasts Nov 1 to April 30 only- Shall be provided in accordance with Attachment D-MDSS System Requirements.
B.3.6	Long-Term Forecast shall be provided once daily and shall cover a period of 1 to 10 days. The long-term forecast shall be provided year round.
B.3.7	A system shall be provided that allows a user to obtain all forecast and treatment data, both in the office and at home, through an internet connection at all times.
B.3.9	Forecasting parameters shall be selectable enabling each one to be turned on or off.
B.3.10	Forecasts shall be displayed hourly for 48 hours and daily for 10 days.
B.3.11	Users shall be able to select customizable alerts for specific weather data or sensor data. Limits shall be selectable for each alert. Users will have the option of getting alerts via text, phone, or email
Category 4	**Vendor Services**
B.4.1	As it pertains to this contract Business days are defined as 8:00 a.m. to 5:00 p.m. Eastern Standard Time, Monday thru Friday.
B.4.2	WMT Installation – A minimum of 10 AVL/GPS WMT packages, at two locations (total of 20 equipment packages), shall be installed by Department staff with onsite guidance by the contractor. A detailed installation manual must be provided to Department before installation.
B.4.3	On-site maintenance training – The contractor shall provide at least one on-site, in-person training session on preventative maintenance and basic repairs of AVL equipment packages and any furnished sensors. Site to be determined by CCI
B.4.4	All trainings shall be available on-site and consist of at least ½ day sessions. Training sessions shall accommodate up to 15 people per session. Training materials shall be given as hard copy and available electronically. Site to be determined by CCI
B.4.5	Specialty Installation Tools – The contractor shall provide any and all specialty tools required to perform the installations.
B.4.6	User Training – The contractor shall provide at least one annual training session on how to use all furnished software.
B.4.7	Collected data shall be accessible to Department staff on-line for a period of up to two (2) years from date of collection. Data beyond the 2 year period may be archived but shall be reinstated online and available to the users upon request by the Department. Data shall be archived indefinitely.
B.4.8	Archived Data – All data collected on behalf of the Department shall be stored by the vendor for the entire life of the contract and must be readily accessible on website within 2 business days of a request.
B.4.9	All data collected is the property of the Department and shall be turned over to the Department at the end of the contract.
B.4.10	Technical Support – The contractor shall provide support via telephone and email

	for maintenance problems regarding the AVL system hardware or software and provide remote assistance within one hour of problem detected. On-site support must occur within 2 business days if requested by CCI.
B.4.11	Single Contact – The contractor shall provide a single point of contact for technical support for the entire AVL system, with the exception of non-contractor furnished sensors and communications.
B.4.12	Software Edition or Version – Unless otherwise specified, the software and firmware must be the latest edition or version offered.
B.4.13	Spares – The contractor shall have sufficient amount of replacement AVL equipment packages on hand to provide Department replacement packages within 2 business days of being notified of defective/non-functioning equipment to provide a consistent level of service.
B.4.14	Preventative Maintenance – Documentation on preventative maintenance of hardware will be included with AVL Equipment Packages and be required to occur no more than twice a year.
B.4.15	AVL Data Management and Access – the AVL information collection, storage, and mapping website shall be designed, owned and operated by the contractor at a location of the contractor's choice, outside of the Department network and accessible to the Department and other agencies via the internet, using a standard web-browser.
B.4.16	The contractor server must receive data from all vehicles with AVL purchased to be processed on a secure website.
Category 5	**Website, Mapping, and Reports**
B.5.1	User Website - The system must be a web-hosted solution accessible from any web browser with the appropriate User Name and Login credentials.
B.5.2	User Logins – The system must provide unlimited user names and unlimited access. It is expected that potentially 500 Department staff statewide will require user names and passwords.
B.5.3	Multiple users shall be able to access the information simultaneously from multiple locations.
B.5.4	User privileges shall be based on assigned username and password. System shall allow modification of the number of vehicles to be monitored, sensors to be monitored and monitor characteristics. User access levels shall be configurable for type of user (i.e. administrator, management, various office/agency level), as defined by the CCI.
B.5.5	Database – The AVL database system must have the ability to be in continuous operation 24 hours per day, 365 days per year and must be capable of handling year-end changes and daylight savings changes with no impact to the system.
B.5.6	Database Backup/Recovery – The AVL database system must provide for automatic recovery after any type of network failure. System must allow a means of automatic data archival and backup without system interruption.
B.5.7	Database Access – Data can be accessed, stored and archived by the Department in a relational database. Database should be designed to preserve the integrity of

	collected data, include a dictionary and relationship diagram for translation, and facilitate access and integration into other systems and applications.
B.5.8	Website – Data must be on-line at all times. Vendor must take precautions to prevent downtime.
B.5.9	User interface shall utilize point and click features as much as possible to increase ease of use and limit input user error.
B.5.10	Website - Color coded icons for at-a-glance status will be used.
B.5.11	Data Access - The system must include a web services Application Programming Interface (API) to allow read only secured access for raw data retrieval for use in other relational database applications (such as GIS mapping or other customer uses).
	Mapping
B.5.12	Users shall be able to view the position of their fleet vehicles at any point of time via a standard web browser on from a computer, tablet, and/or smartphone. The primary display shall be a map view of fleet vehicles and indicate the status of vehicles on when it last reported.
B.5.13	Each vehicle on the map should have a unique identifier, such as license plate, as determined by CCI.
B.5.14	The system must provide a minimum of the following mapping and reporting information: a. Last known asset location map view – fleet wide view b. Dispatch map (full screen "live" view) c. Asset last location relative to home (pre-determined address) d. Asset Odometer readings e. Total engine hours f. Last time asset reported in g. Last known location (individual asset map view) h. Historical trip report (individual asset map view) i. Raw data report showing exact data string as it was sent from spreader control (required for analyzing reports) i. Speed ii. Idling iii. Operating during "off" hours iv. Power v. Geo fence (in/out) vi. Temperature (custom attention required) j. View Maintenance History/Update Maintenance Record k. Ping Asset (Short Message Service(SMS) report) n. Distance measurement tool within the fleet-wide map view
B.5.15	The system must also provide the following mapping and reporting information: a. Vehicle Identifier (required) This should be an identifier that is unique to the organization from which the data is being collected. b. Time (required) This should be a complete description of the date and time of the report

	to within 1 second of accuracy. It can be in the form of a string (e.g., "12/20/2013 3:43 AM EST" or "1-20-2005 9:43 UTC") or numeric (such as a Unix timestamp, which is a count of seconds since a certain point in history). The form of string representations of the date & time is flexible, but should include at least the year, month, day, hour, minute, second and time zone of the observation (Eastern Standard Time). c. Location (required) Location information should be provided in the form of a GPS latitude and longitude associated with the vehicle's location at the time of the report. Three or more decimals of accuracy are required. d. Lane Identifier (required) This should be an identifier that can be used to uniquely determine the lane or lanes that a report applies to. e. Maintenance Data i. Plow Position (optional) ii. Scraper/Underbody Position (required) iii. Wing Position (optional) iv. Material Applied (required) v. Material Form (required) vi. Application Rate (required) vii. Application Rate Units (required) viii. Road Temperature (required) ix. Air Temperature (optional) x. Camera Feed (optional) Programmed to collect a time stamped forward camera image when option is installed.
B.5.16	The map display shall be such that vehicle position and status automatically update on screen without any input form the end-user, additionally, end-users shall be able to view the status of monitored on-board vehicle equipment.
B.5.17	The system shall allow viewing of a vehicle in motion leaving tracks or "breadcrumbs" as it travels with arrow indicators for direction and showing all operations (GPS & Telematic data) as they occur including exact street location. Users shall be able to view the above mentioned data for their entire fleet or select a specific vehicle(s) for a login session using a Filter Tool.
B.5.18	User shall be able to toggle back and forth between mapping interface and other features without having to close screens.
B.5.19	The System shall have the capability to enter an address or select a landmark to display at a minimum the 5 closest vehicles to that location including vehicle ID & distance to the specified location.
B.5.20	The system must have the capability to create, edit, and delete landmarks and/or geofences to be displayed on the map. In addition the landmark/geofence shall be identified in the reports.
B.5.21	The system must have an easy 'intuitive' navigation sequence (i.e. navigator bar and/or tabs for easy access to various functional screens). Tools shall include but not be limited to: • Map navigational tools (zoom in/out, center, pan, etc.);

	• Automatic Vehicle Location Tool; • Breadcrumbs; • Filter Tool; • Historical Data; and Reports.
B.5.22	User shall have options to select from different map views of the map in order to accommodate varying business requirements, desktop equipment performance and internet connectivity.
B.5.23	The system shall include a playback feature allowing users to review historical data for selected vehicle(s), date(s) and timeframe. This data shall be made outputted via map based (graphical) and/or text based report. When reviewing the data graphically, the playback feature shall have pause, fast forward and rewind capabilities for ease of use.
B.5.24	Playback history shall include the ability to leave tracks or "breadcrumbs" depicting progress and direction along a roadway. This function shall enable the user to view data that has been collected from the vehicle (GPS and telematic data).
B.5.25	Maps – fully licensed maps included. Maps must also integrate with the Department's GIS framework which includes all route and mile marker identifications.
B.5.26	Reports shall be available for users by interactively selecting an area using the map interface.
	Reports
B.5.27	Data Exports – Reports must be exportable to Microsoft Excel, Microsoft Word, .csv format , and other relational databases.
B.5.28	Vehicle Usage Report - The system must provide Daily, Weekly, Monthly and Custom usage reports to accurately display vehicle utilization as well as hourly usage reports to reflect how many minutes in each hour a vehicle was in use.
B.5.29	M5 Vehicle Usage Reports - The system must also be capable of formatting the data for vehicle usage according to Attachment C, "M5 Standard Meter Interface Directions".
B.5.30	Vehicle Mileage Report **(All Vehicles)** – The system must provide a vehicle mileage report with user selectable date ranges showing miles traveled per day and first start/last stop times for each day in the selected date range.
B.5.31	Vehicle Hours Report **(All Vehicles)** – The system must provide an engine hour report with user selectable date ranges showing engine hour usage per day and first start/last stop times for each day in the selected date range.
B.5.32	Custom Reports **(WMT Fleet only)** – The system must provide a custom input usage report with user selectable date ranges showing usage of monitored auxiliary equipment such as underbody blades, temperature sensors, and additional components. Report must be able to show all activity or be run on a single auxiliary equipment input such as plow position.
B.5.33	Material Usage Report **(WMT Fleet only)** - System must provide material usage reports to accurately track the amount of granular material, pre-wet and/or direct liquid that was applied to a predefined section of roadway, or "zone". (for spreader integrated equipment only).

B.5.34	Vendor must be able to provide data from all salt spreader controllers into one report. Users shall be able to select all, multiple, or individual vehicles and date(s) and timeframe for each report. Report shall output at a minimum vehicle ID, date/time, vehicle spreading time/distance, deadheading time/distance, vehicle total travel time/distance, dry material usage (pounds / lane mile), liquid material usage, avg. application rate.
B.5.35	The system shall provide easy to use reporting tools to provide all reported data. Reports should have the option of exporting to Excel, .CSV or other relational databases.
B.5.36	The system shall be able to generate summary reports based on the user's input parameters. Each user shall have the ability to configure the parameters included in a report
B.5.37	Reports shall be configured to select either a single vehicle or group of vehicles.
B.5.38	It must be possible to generate additional user defined reports. These include, but are not limited to:
a.	Zone/Route report
b.	Fleet Start/Stop Report
c.	Individual Vehicle Mileage Report
d.	Daily/Weekly/Monthly Asset Usage Report
e.	Custom Asset Usage Report
f.	Custom Input Usage Report (6 discreet inputs)
g.	Asset Distance Report
h.	Exception Reports
B.5.39	In addition to standard reports, the system must be capable of generating exception reports for parameters such as • Stop times • Speed • Idle time • Zones • Input based exceptions (i.e. Panic buttons, PTO times, etc.) • Data logging exceptions (i.e. mileage, odometer value, etc.) • Exception reports
B.5.40	Exception reports shall be configurable by each user and the capability to generate an exception report from a combination of 2 or more parameters must be possible. I.e it must be possible for a user to create an exception report for WMTs that are applying material and traveling above a requested speed.
B.5.41	All exception report shall have the capability to be displayed on the website and as well as being sent automatically to specified users via email and or text message (as defined by the user).
B.5.42	The system shall provide an easy to use reporting tool to provide vehicle and material information such as date, time started, time completed, total miles traveled, total miles spread, total dead head miles, material usage (Ton), application rate, Liquid usage (gal), liquid application rate, and totals of the above information per snow event/storm.

Appendix C MDOT MDSS Requirements

Attachment D:
Maintenance Decision Support System (MDSS) Requirements

The MDSS ("System") shall detect, diagnose, forecast, and display surface transportation weather phenomena, road condition information, and winter maintenance treatment recommendations (described herein) for supporting winter road maintenance operations (e.g., snow plowing, deicing, anti-icing, etc.).

The System shall include the capability to selectively archive data and display archived data and products. The System shall include the capability to routinely monitor the system status. The System shall be fault tolerant with high reliability. The System shall be designed in accordance with standard commercial practices for software development. The System shall be designed to make reasonable allowance for expansion of computing power. The System software shall be designed to ensure that it can run on commercial-off-the-shelf hardware commonly available; that is, no special hardware development will be necessary. The System shall be designed to ensure that it can incorporate weather and road data from disparate sources (e.g., National Weather Service (NWS), Department AVL/GPS, Department Connected Vehicle projects, mesonetworks, RWIS, AWOS, etc.). The System (including all servers and displays) shall be synchronized using a time standard. The System shall include the capability to playback historical data for demonstration, training, and analysis purposes. The System shall use Local Time (LT) for all displays.

The System displays shall be implemented in English with English units as the default setting. The System shall integrate environmental (weather), road condition and transportation operational data in a manner that allows it to provide predictions of pavement conditions (e.g., pavement temperature, precipitation accumulation, anti-icing chemical effectiveness, etc.) associated with winter road maintenance.

Using the pavement condition and environmental prediction information, the System shall provide decision support guidance to winter road maintenance practitioners and the guidance shall include information related to treatment options (e.g., plow, deice, anti-ice, etc.), timing of application, location of application, and amount of application) based on current and predicted weather conditions. The System shall notify users when data updates (e.g., new forecasts) are available and the updates shall be loaded when the user selects to do so.

MDSS Coverage Area

The System shall be designed to operate (via configurable files) in any user-defined region (e.g., state, city, county, etc.) that has input data necessary to support its operations. The System shall generate weather forecasts for zones or regions around the State as identified by the user (e.g., forecast zones, maintenance zones, etc.). The System shall provide weather and road condition products (via configurable files) for road routes (maintenance routes) identified by the user. The System shall be configured to provide weather and road condition products for user identified road maintenance routes.

Weather Forecast Products

Weather forecast products refer to weather elements above the ground. Weather forecast products shall be provided out to at least 48 hours. Weather forecast products shall have a temporal resolution of at least one hour. Weather forecast products shall be updated no less than every three hours; that is, a new 48-hour forecast shall be provided every three hours.

The following weather forecast products shall be provided 2 meters above ground level (AGL), unless otherwise noted:

a) Surface air temperature
b) Surface dew point
c) Surface relative humidity
d) Surface wind speed & direction
e) Surface wind gust
f) Precipitation type
g) Precipitation rate
h) Snowfall accumulation (e.g., 3-hr total, 6-hr total, and total accumulation during the forecast period)
i) NWS watches, warnings and advisories

The weather forecast products shall be geo-referenced to the DOT domain using map overlays that include roads, road designators, political boundaries, etc.

Surface Air Temperature Forecast Product

The output (content) of the Surface Air Temperature Forecast Product on the display shall have the following characteristics:

a) The surface air temperature shall be provided in degrees Fahrenheit
b) Time series information (text and graphical formats) of the surface air temperature shall be provided.
c). Reference lines (configurable) associated with frequent thresholds (e.g., freezing) shall be provided.

Surface Dew Point Temperature Forecast Product

The output (content) of the Surface Dew Point Temperature Forecast Product on the display shall have the following characteristics: a) The surface dew point temperature shall be provided in degrees Fahrenheit b) Time series information (text and graphical formats) of the surface dew point temperature shall be provided.

Surface Wind Speed & Direction Forecast Product

The output (content) of the Surface Wind Speed & Direction Forecast Product on the display shall have the following characteristics:

a) The wind speed shall be provided in statute miles per hour by default
b) The wind direction shall be provided in degrees with respect to true north.
c) Time series information (text and graphical formats) of the wind speed and direction

Surface Wind Gust Forecast Product

The output (content) of the Surface Wind Gust Forecast Product on the display shall have the following characteristics: a) The wind gust speed shall be provided in statute miles per hour. c) Time series information (text and graphical formats) of the wind gust speed shall be provided.

Conditional Probability of Precipitation Type Forecast Product

The conditional probability of precipitation type is a product that describes the probability that a particular precipitation type (e.g., rain, snow, freezing rain, etc.) will occur if there is any precipitation at all.

The Precipitation Type Forecast Product shall include the conditional probability of precipitation type. That is, the user shall be able to view the probability of each type of precipitation as well as the predominant type.

a. The precipitation type shall be provided for at least the following:
    a. Rain
    b. Snow
    c. Ice
    d. Mixed (rain, snow, ice)
b. The predominant precipitation type (the type that the model selects as the most likely kind that will occur) shall be identified.
c. Time series information (text and graphical formats) of the predominant precipitation type shall be provided.

Precipitation Rate Forecast Product
The output (content) of the Precipitation Rate Forecast Product on the display shall have the following characteristics:

a. The liquid equivalent precipitation rate shall be provided in inches per hour (to a precision of a hundredth of an inch).
b. The snowfall precipitation rate shall be provided in inches per hour (to a precision of a tenth of an inch).
c. Time series information (text and graphical formats) of the precipitation rate shall be provided.

Snowfall Accumulation Forecast Product
The Snowfall Accumulation Product shall indicate the amount of snow that is expected to reach the surface (ground) over a specified period. Melting of precipitation due to warm surface conditions is not considered in this product.

The output (content) of the Snowfall Accumulation Forecast Product on the display shall have the following characteristics:

a. The snowfall accumulation shall be provided in inches (to a precision of a tenth of an inch).
b. Time series information (text and graphical formats) of the snowfall accumulation shall be provided.
c. Snowfall accumulation shall be provided at user-defined temporal increments out to 48 hours (e.g., 3-hour, 6-hour, 12-hour accumulation, etc.).

Weather Observation Products
Weather observation products shall be provided by the System. The weather observations products shall be geo-referenced to the DOT domain using map overlays that include roads, road designators, political boundaries, etc.

Weather observation products shall include, but not be limited to, observations from the following sources: NWS, DOT, FAA, and other sources as available.

Weather observation products shall include the following parameters, where available:

a. Air temperature (degrees F)
b. Relative humidity (percent)
c. Dew point (degrees F)
d. Wind speed & wind direction (miles per hour & degrees with respect to true north)
e. Radar Imagery

The weather observation products shall update as new data arrive. The output (content) of the weather observation products on the display shall have the following characteristics:

a. The surface observation data shall expire off the screen after a configurable number of minutes.
b. The expiration time shall be independently configurable for each observation product.
c. Time series (text and graphical formats) shall be provided.
d. Animation of the observations shall be provided.

adar Product

The radar product shall be based on data provided by NOAA. Other radar data sources may be used if applicable (e.g., FAA Terminal Doppler Weather Radar, local media owned radars). The radar product shall be based on the reflectivity (intensity) field. The radar product shall update as new data arrive.

The output (content) of the radar product on the display shall have the following characteristics:

- The radar reflectivity (intensity) field shall be displayed (plus color legend).
- Radar products shall be provided for user-defined domains.

NWS Watch, Warnings and Advisories Product

NWS watch, warnings and advisories for the DOT domain shall be provided.

The NWS watch, warnings and advisories shall include, but not limited to:

a. Winter storm watches and warnings
b. Flood watches and warnings
c. Flash flood watches and warnings
d. Severe thunderstorm watches and warning

e. Tornado watches and warnings
f. High wind watches and warnings
g. Special weather statement
h. Freeze watches and warnings
i. Winter weather advisories
j. Dense fog advisories
k. Snow advisories

The NWS watch, warning and advisory product shall be provided in text format. Graphical depictions of NWS watches and warnings may be provided, where applicable.

When an NWS watch, warning or advisory is in effect for an area (configurable) that covers the DOT domain, the display shall provide an indicator (e.g., highlighted button).

Road Condition Observation Products

Road condition observation products shall be provided and shown on the display.

Road condition observation products may include, but not be limited to, observations or measurements from the following sources:

a. Environmental Surface Stations (ESS)
b. Road Weather Information Systems (RWIS)
c. GPS/AVL data and Connected Vehicle data from Department fleet

(The CCI will decide which sources are used, and how).

Road condition observation products shall include the following parameters, where available

a. Road temperature (degrees F)
b. Subsurface temperature (degrees F)
c. Chemical concentration on road (percent by weight)
d. Freeze point temperature (degrees F)
e. Pavement condition as: Wet, Dry, or Chemically Wet
f. Snow, frost, and ice depth (inches
g. Blowing snow (yes/no)
h. Visibility (miles or fractions of miles)

The road condition observation products shall update as new data arrive. The output (content) of the road condition observation products on the display shall have the following characteristics:

a. The surface observation data shall expire off the screen after a configurable number of minutes
b. The expiration time shall be independently configurable for each observation product.
c. Viewing of the product shall be user selectable.
d. Time series (text or graphical formats) of the observations shall be provided.
e. Animations of the road condition products shall be provided.

Road Condition Prediction Products

The road condition prediction products shall be provided out to at least 48 hours. The road condition prediction products shall have a temporal resolution of at least one hour. The road condition prediction products shall be updated every three hours; that is, a new 48-hour forecast shall be provided no less than every three hours.

The following road condition prediction products shall be provided:

a. Road temperature
b. Road chemical concentration
c. Snow depth on road
d. Blowing snow potential
e. Pavement frost potential
f. Pavement condition

Road Temperature Prediction Product

The Road Temperature Prediction Product shall be provided at predefined (configurable) locations associated with each DOT maintenance route. The Road Temperature Prediction Product shall be based on a thermal energy balance model and/or empirically based model.

The output (content) of the Road Temperature Prediction Product on the display shall have the following characteristics:

a. The road temperature shall be provided in degrees F
b. The road temperature shall be presented graphically at each forecast location within the chosen (configurable) maintenance routes.
c. Time series information (text and graphical formats) shall be provided.

Road Snow Depth Prediction Product

The Road Snow Depth Prediction Product shall provide information that describes the amount of snow that is predicted to accumulate on a road surface without traffic and for specific winter maintenance treatments

Calculation of the Road Snow Depth Prediction Product shall take into account (at a minimum) the forecasted precipitation type and rate, and road temperature to estimate the amount of snow that will accumulate on the road surface.

The Snow Depth Prediction Product shall be provided at predefined (configurable) locations within each DOT maintenance route.

Calculation of the Snow Depth Prediction Product shall take into account treatment options including the amount of snow expected to accumulate on the road when; a) no treatment is performed, b) the recommended treatment is performed, and c) a user-defined treatment is performed.

The output (content) of the Snow Depth Product on the display shall have the following characteristics:

a. The snow/ice amount shall be given in inches by default (to a tenth of an inch)
b. The snow depth shall be shown for various treatment options including: no treatment, recommended treatment, and user-defined treatment.
c. The road snow depth shall be presented graphically at each forecast location associated with the chosen (configurable) maintenance routes.
d. Time series information (text and graphical formats) of the road contamination accumulation shall be provided.

Blowing Snow Potential Product

The Blowing Snow Potential Product shall provide information that describes the likelihood for blowing snow (e.g., low, medium, high). Calculation of the Blowing Snow Potential Product shall take into account (at a minimum) recent snowfall characteristics, the forecasted precipitation type and rate, predicted wind speed, local topography, and predicted air temperature. The Blowing Snow Potential Product shall be provided at predefined (configurable) locations within each DOT maintenance route.

The output (content) of the Blowing Snow Potential Product on the display shall have the following characteristics:

a. The likelihood value for blowing snow (e.g., low, medium, high or as a percentage)
b. Likelihood values shall be provided at hourly increments.
c. Likelihood values shall be provided at hourly increments.
d. Time series information (text and graphical formats) shall be provided.

Pavement Frost Potential Product

The Pavement Frost Potential Product shall provide information that describes the likelihood for frost on the pavement surface (road and/or bridges) (e.g., low, medium, high or as a percentage). Calculation of the Pavement Frost Potential Product shall take into account (at a minimum) predicted pavement temperature, predicted precipitation type and rate, predicted wind speed, predicted relative humidity (considerations of dew point/frost point), and predicted air temperature. The Pavement Frost Potential Product shall be provided at predefined (configurable) locations within each DOT maintenance route.

The output (content) of the Pavement Frost Potential Product on the display shall have the following characteristics:

a. The likelihood value for pavement frost (e.g., low, medium, high or as a percentage)
b. Likelihood values shall be provided at hourly increments
c. Likelihood values shall be provided for each road forecast segment (e.g., plow route).
d. Time series information (text and graphical formats) shall be provided.

Pavement Condition Prediction Product

The Pavement Condition Prediction Product shall provide information on the predicted state of the pavement and include:

a. Wet
b. Dry
c. Chemical wet
d. Percent coverage of snow and
e. Snow, frost, and ice depth (inches)

The output (content) of the Pavement Condition Prediction Product on the display shall have the following characteristics:

a. The pavement condition shall be presented in text format indicating the pavement condition (e.g., wet, dry, chemical wet, etc.) for each road forecast location (e.g., plow routes).
b. Time series information (text and graphical formats) shall be provided.

Calculation of the Pavement Condition Prediction Product shall take into account the pavement condition when; a) no treatment is performed, b) the recommended treatment is performed, and c) a user-defined treatment is performed.

Forecast Confidence Product

A measure of confidence shall be provided for the following weather forecast and road condition prediction products:

a. Snow accumulation
b. Precipitation type
c. Road temperature

The calculation of prediction confidence shall take into account recent statistical performance of each parameter and other appropriate metrics.

The output (content) of the Prediction Confidence Product on the display shall have the following characteristics:

a. The prediction confidence shall be given as a percentage, and shall be able to be displayed graphically.

b. Error statistics shall be calculated that reflect recent skill.
c. Time series information of the prediction confidence or error statistics shall be provided for the above-mentioned products.

Generation of Treatment Recommendation Predictions
The System shall provide treatment recommendation predictions for winter road maintenance at user defined (configurable) locations (e.g., plow routes).

The System shall provide treatment recommendation predictions out to no less than 24 hours into the future.

The winter maintenance rules of practice used in the System shall be based on the Manual of Practice for Effective Anti-Icing Program and NCHRP report #526 - Snow & Ice Control: Guidelines for Materials and Methods, and be configurable, as necessary, to reflect local DOT practices.

Treatment recommendations shall include the following for each user defined route:

a. Recommended initial treatment start time
b. Recommended subsequent treatment start time
c. Recommended treatment type (e.g., chemical, abrasives, plow)
d. Recommended chemical type based on available chemicals as identified by the Department
e. Recommended material rate (e.g., amount per lane mile)
f. Recommended pre-treatment type (solid or liquid), where applicable

The System shall have a capability to incorporate constraints (configurable) for each route so that irrelevant treatment recommendations are not provided. For example, the use of NaCl should not be recommended if the user does not use that chemical. Constraints may include:

a. Available materials (e.g., NaCl, $MgCl_2$, $CaCl_2$, abrasives etc.)
b. Application rate limits (based on truck spreading limits)
c. Route cycle limits (minimum turn around time to repeat treatments)

Treatment recommendations shall be calculated, to the greatest extent possible, using a combination of current observational data on the state of the roadway and predicted weather and road conditions.

Treatment recommendation calculations should consider, to the greatest extent possible, factors that impact treatment effectiveness (e.g., chemical scatter, splatter, traffic impacts, spreader characteristics, etc.).

System Alert Function
The System shall provide a capability to alert the user when specific data thresholds (configurable) have been exceeded. Users shall be able to query the System and view the information related to an alert.

The System shall indicate that an alert is active by one or more of the following methods: a) Highlighting an alert button b) Changing the color of an alert button c) Flashing an alert button d) Audible alert (finite series of beeps or tones) The System shall include a capability to send e-mail or text message notices or cell phone calls (to a configurable list of aliases) when specific alerts (configurable) are generated.

Display

The display shall have the following general capabilities:

a. Ability to view plan-view graphics
b. Ability to view time-series information
c. Animation
d. Time selection whereby the user can select the time period for data viewing
e. Print function
f. Alert function
g. Ability to review historical data
h. Ability to select viewing area
i. Ability to select products for viewing
j. Help function
k. Ability to combine data on time series plots
l. Ability to configure data ranges (scale) for each time series plot
m. Ability to overlay and combine graphical products

In vehicle display:

a. Ability to view plan view graphics
b. Ability to view local radar
c. Ability to view route specific treatment recommendations
d. Ability to view route specific weather and pavement forecast

Map Overlays

The System shall make it straightforward (e.g., via configuration files) to incorporate new map data.

Map overlays shall be available for the following:

a. Roads (State and local highways and secondary roads)
b. Road designators (e.g., route numbers, etc.)
c. Road Control section and mile marker identification.
d. Political boundaries (e.g., States, counties, maintenance zones, MDOT region and TSC area, etc.)
e. Cities
f. Weather and road condition observation sites

Data Archive and Historical Data Review

The System shall include a short and long-term data storage capability. The process of saving data shall not interfere with the normal operation of the System.

Short-Term Archive

The short-term archive shall consist of the latest fourteen (14) days of data. The oldest stored data shall be routinely (scrubbed) overwritten by new incoming data, such that the integrity of incoming data is preserved. Data within the short-term archive shall be viewable by selecting the date and time of interest from the display interface.

Long-Term Archive

The long-term archive shall consist of data sets specifically saved by the user. The System shall not delete (scrub) data within the long-term archive. The user shall have the capability to select the date, time, and filename for the long-term archive. The System shall provide a capability for the user to review data from the long-term archive. This review shall not interfere with the operation of the real-time system. This requirement could be met by having a separate System available to view data from the historical archive.

Historical Data Viewer
The system shall have a capability to view (recent) historical weather and road condition prediction products together with actual observational data to give the user an indication of the performance of the weather and road condition predictions.

Users shall have the ability to select any of the forecasts from the previous 24-hour period. For example, the user shall be able to select a forecast 6 hours previous and compare the predicted conditions to the actual conditions.

Security
Means shall be provided to prevent the unauthorized use or misuse of the facilities provided in the System. This particularly applies to those functions that can be used to reconfigure or change the operating status of the System or subsystems.

Security shall be provided (e.g., password protection) to ensure that the System cannot be accidentally disabled from any display device or network system.