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Utilization of AVL/GPS Technology Case Study: Washington State 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 Washington State 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 Washington State DOT Winter Maintenance Operations

This section provides an overview of this Case Study report detailing how the Washington State Department of Transportation (WSDOT) 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 WSDOT 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. WSDOT's survey responses are also included in Appendix A of this case study report.

1.2 Agency Characteristics

WSDOT is divided into six different regions as illustrated in Figure 1. These are the Olympic, Southwest, Northwest, North Central, South Central, and Eastern regions. Within each region, WSDOT winter maintenance staff are structured into the following general positions:

Region Maintenance Engineer: Responsible for overseeing all Areas within the Region in terms of response to winter storms. May be responsible for allocating some of the Region's resources to other Regions of the state in the event of severe weather impacting that specific region.

Area Maintenance Superintendent: Responsible for monitoring maintenance supervisors within each of the respective 24 Areas of the state, and how each Area is responding to winter storms within that Area / Region. Reports to Region Maintenance Engineer and communicates with Maintenance Supervisors during winter events.

Area Maintenance Supervisor: Responsible for overseeing multiple snow plow operators performing along assigned snow plow routes within that part of the Area within the Region.

It was noted that Area Maintenance Superintendents and Supervisors maintain communication with each other utilizing vehicle radio equipment. Snow plow operators within an Area may be called upon to divert from their planned route to assist with snow clearance along other roads as needed.

Figure 1. WSDOT Regions[1]

[1] Source: http://www.michigan.gov/WSDOT/0,4616,7-151-9623-36042--,00.html

1.3 Agency Interviews

WSDOT staff were interviewed over a two-day period between Dec. 19th, 2017 at WSDOT offices in Olympia, WA. Table 1 lists those individuals that were interviewed for the project.

Table 1. Agency Interview Dates / Times

Staff Interviewed	Date / Time	Subjects Discussed
Joe Schmit, Technology Resource Manager, Maintenance Operations Division **James Morin**, Snow and Ice Program Manager **Andrea Fortune**, Maintenance Policy Branch Manager **Kimberly Williams**, WSDOT Purchasing Manager **Oai Tang**, Maintenance and Operations Specialist **Keisha Chinn**, GIS and Data Systems Manager **Peter Burkhard**, Technology Resource Program Specialist Additional IT Support Staff (via phone) Additional Maintenance Superintendents and Supervisors (via phone)	Dec. 19th / 8:00am	Hardware installation Technology issues and testing Operations Maintenance 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

Figure 2. WSDOT Snow Plow Vehicles

2. Degree of AVL/GPS Implementation

This section of the report outlines the extent to which AVL/GPS technology has been deployed for WSDOT winter maintenance operations.

2.1 AVL/GPS Project Background

WSDOT began working with AVL/GPS technology through a pilot project in Tacoma, WA where WSDOT was initially using Precise AVL system in combination with pre-existing Force America spreader controllers. Over time, WSDOT allowed for other Regions to install and integrate Precise AVL hardware with existing Force America spreader controllers, while some WSDOT Regions installed Location Technologies' LT6 AVL/GPS system around 2010. The LT6 AVL hardware installed on WSDOT vehicles was implemented with 2G cellular technology as a means of center-to-field communications.

WSDOT was notified by PreCise around 2014-2015 that an upgrade to the vehicle's IX-302 hardware would be required in order to prevent disruption of WSDOT's center-to-field communications with those vehicles while in operations. This was due to a phasing-out period of the 2G cellular network which would soon be shut down.

Given that new PreCise hardware would need to be procured, and that different AVL systems were being used by different Regions, WSDOT saw as an opportunity to not only procure and upgrade the existing AVL systems, but also establish a consistent approach with their AVL/GPS system on a statewide basis. As such, WSDOT developed and issued an RFP to procure a vendor to provide AVL hardware and software for all WSDOT snow plows throughout the state.

2.2 Size of AVL/GPS Implementation

WSDOT has procured and installed AVL/GPS equipment on approximately 400 of its 500 snow plow vehicles throughout the state. The AVL equipment was procured from Location Technologies in 2015 and was installed by WSDOT vehicle technicians.

2.3 AVL/GPS Vendor Solution

Location Technologies was chosen as the AVL/GPS vendor for the WSDOT snow plow fleet to provide LT6 AVL hardware. Further discussion of the hardware is presented in Section 3 of this report.

3. Level of System Integration

This section details the LT6 AVL/GPS system equipment that was installed for the Washington State DOT and the level of integration with other technology on winter maintenance vehicles.

3.1 Vehicle Hardware

The LT6 AVL/GPS system hardware is pictured in Figure 3 in an un-covered and covered configuration for reference. Additional images of the AVL/GPS system as well as its typical installation are provided in Figure 4.

Figure 3. WSDOT AVL/GPS System Hardware Units (Un-covered and Covered)

Figure 4. WSDOT Snow Plow Equipment and Location of LT6 AVL/GPS System

One of WSDOT's basic installation requirements was to ensure the visibility of the power and communications indicator lights on the front of the AVL device. This allows operators to perform a visual check of the AVL hardware to confirm an operational status prior to beginning snow plow operations. This visual verification is also a primary health check for the AVL equipment. Another requirement was to ensure the AVL device was installed at a location that was accessible for maintenance.

Figure 5. LT6 AVL/GPS System Mounting Location

WSDOT has integrated the vehicle's spreader controllers and air/pavement temperature sensors with the LT6 AVL hardware unit. WSDOT's winter maintenance vehicles have a variety of spreader controllers from Force America, DICKEY-john, Parker, Raven and Schmidt. The Force America 5100 model of spreader controller is pictured in Figure 6.

Figure 6. WSDOT Spreader Controller Equipment and Screen

The pavement temperature sensors utilized by WSDOT is pictured in Figure 7. The majority of the pavement temperature sensors utilized by WSDOT were Vaisala sensors. WSDOT also utilized RoadWatch sensors. Most of the sensors were tied into spreader controllers. For vehicles with Parker spreader controllers, pavement temperature sensors were connected to the LT6 AVL equipment directly. WSDOT was also testing a wireless sensor by Precise.

The location of the pavement temperature sensor generally varies by WSDOT Region given the different maintenance staff involved in the installation process. The placement of the sensor as shown in Figure 7 aiming directly downward and in a location that limits road spray from gathering on the sensor was noted as an ideal location.

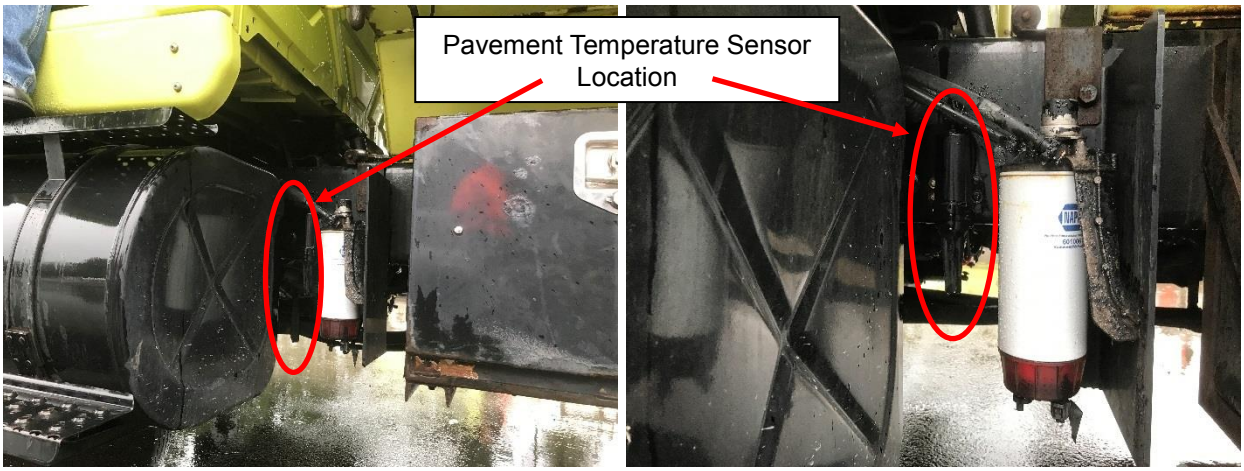

Figure 7. WSDOT Pavement Temperature Sensor Location

Plow position sensors were also integrated with the AVL system to detect plow up/down and track usage. Plow position sensors were only installed to track front plows. Some WSDOT winter maintenance trucks were also equipped with wing plows or belly plows, however they were not tracked.

In addition to plow position sensors, WSDOT winter maintenance trucks also equipped with hydraulic sensors for front plows as shown in Figure 8. The hydraulic sensors were used to indicate the plow position of the vehicle to the spreader controller.

Figure 8. WSDOT Snow Plow Hydraulic Sensor Location

There is a variety of spreader equipment from various manufacturers in different Regions of the state, which is determined as part of the vehicle up-fitting process that occurs in the state. The spray tank and spreader equipment of the WSDOT snow plows are pictured in Figure 9.

Figure 9. WSDOT Snow Plow Spreader Equipment and Spray Tank

The LT6 AVL hardware was not integrated with the vehicle's OBD-II port to gather vehicle diagnostic information, given that as a separate effort the WSDOT Fleet & Equipment Operations, commonly referred to as the Transportation Equipment Fund (TEF), was implementing Verizon NetworkFleet on vehicles to collect, track and report vehicle diagnostics back to Area Maintenance Superintendents.

3.2 System Software

Location Technologies provided WSDOT two views of the AVL data: a web map view and a reporting engine that includes user tools. Through the LT6 software interface, WSDOT staff can generate pre-defined reports that provide information on vehicle operations and material amounts utilized per vehicle

within an Area. Currently, WSDOT only utilizes a “General Activity” and “Material Summary” report from the software.

WSDOT noted that LT6 made its Application Programming Interface (API) available for the purposes of getting key AVL system attributes, such as GPS coordinates, vehicle ID numbers, and material names, to enable WSDOT to download and report the data such as the vehicle location and other attribute on a GIS software interface developed in-house by WSDOT (Figure 10). Active vehicles in Figure 10 show the location of plows that have their plow down or up, as well as those vehicles applying liquids and material by types.

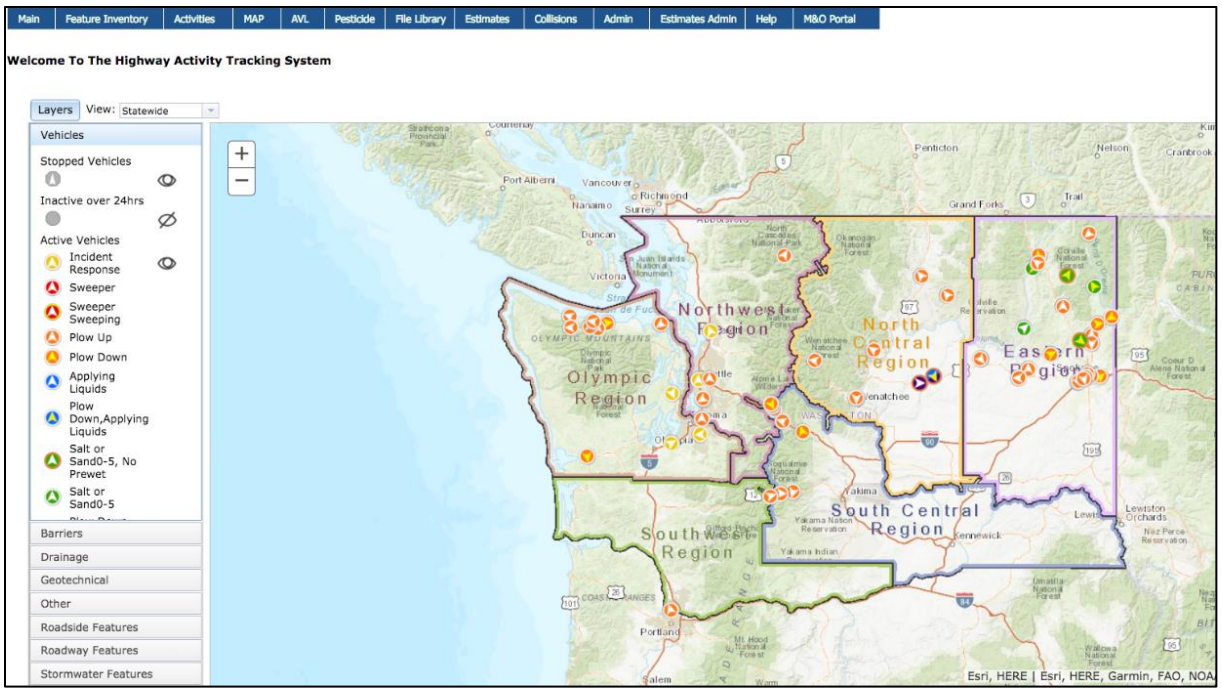

Figure 10. WSDOT In-House Software Interface with AVL Location Data

3.3 Vehicle-to-Center Communications

For field-to-center communications, WSDOT utilizes cellular communications in most areas of the state, which is primarily Sprint as the vendor, although Verizon is utilized in some Regions where it provides greater and more reliable coverage. As part of the contract, Location Technologies secures cellular data communications services and bills WSDOT monthly.

WSDOT also utilizes a state-owned 700 MHz radio system to fill the communications gaps in two Regions that feature more remote areas of the state where cellular coverage is inadequate. The combination of cellular coverage and state-owned radio system works well for WSDOT.

4. Decision Making Process

4.1 Level of Management Involved

The level of management involved from WSDOT in the decision making included the technology resource group as part of the WSDOT Maintenance Division and other WSDOT staff in the Snow and Ice Program.

4.2 Factors Considered

As noted previously, WSDOT had been supporting both a Precise AVL/GPS system and an LT6 AVL/GPS system in different regions of the state. WSDOT was notified in 2014 by PreCise that new IX-302 hardware would need to be procured due to the phasing out of the 2G cellular network. Given that a large amount of new AVL hardware would need to be upgraded, WSDOT saw an opportunity to standardize on the usage of one AVL/GPS system across all regions of the state, which would help to establish a consistent approach with their AVL/GPS system statewide.

The impetuses for WSDOT's AVL system implementation are:

- Real-time tracking of vehicle locations and material usage to support and improve operational efficiency
- Supporting and minimizing tort liability
- As an advisory tool for improving resource planning and route adjustments as well as reducing repeating work on same routes

WSDOT Regions allow snow plow operators to utilize their best judgment on the proper amount of roadway material to use during snow storms. Given this long-held practice of winter maintenance, the addition of other support systems, such as a Maintenance Decision Support Systems (MDSS) procurement and integration with the LT6 AVL system, was not considered for the procurement. In addition, utilization of a MDSS was not considered due to the unique topology for the state. WSDOT staff felt that the current MDSS systems have limitations in providing route-specific or localized weather forecasts with adequate accuracy to assist in winter maintenance operations in the state.

5. Data Collection and Management

5.1 Data Collection

WSDOT noted that in addition to vehicle location data, the LT6 AVL system collects the following data:

- Material type
- Pre-wetting or not
- Material application rate
- Pavement surface and air temperatures
- Plow position (up/down) – front plow only

WSDOT polls the data from the Location Technologies server once every minute to get this information. Data is stored on a high availability WSDOT server and would be saved for at least seven years for future use by WSDOT.

As noted previously, vehicle diagnostics were not gathered through the AVL system as a separate system was implemented by the WSDOT Fleet & Equipment Operations to collect, track and report vehicle diagnostics back to Area Maintenance Superintendents.

5.2 Data Accuracy

WSDOT noted the most desired reporting feature of the AVL/GPS system was the material usage reports. However, the accuracy of the material usage reports has been the biggest challenge of working with the system. WSDOT noted that material usage is calculated based primarily on the application rate and miles of vehicle traveled. WSDOT calibrate the material application annually. The mileage estimates are based on GPS measurements from the AVL system, not the odometer. WSDOT has experienced issues with the accuracy of the GPS measurements. This inaccuracy, in turn, led to an inaccuracy of the material usage calculations. WSDOT noted that enhancement on the material tracking was under development and WSDOT would eventually be able to provide a quality baseline of material usage.

WSDOT staff also noted issues with plow position sensors producing consistent data. Inaccuracy or inconsistency in plow position sensor data was due to exposure to environment. WSDOT is working on finding a solution to address data inconsistency.

5.3 Staffing and Resources

WSDOT performs an internal backup of the AVL data generated from the LT6 AVL system, and has created an in-house web-based software interface that displays the locations of WSDOT snow plows for use by Area Maintenance staff. WSDOT noted that LT6 made its Application Programming Interface (API) available for the purposes of getting key AVL system attributes, such as GPS coordinates, vehicle ID numbers, and material names, to enable the vehicle location and other attribute reporting on the in-house software interface. It was noted that staffing resources were not a concern as WSDOT has the needed resources and skill sets to manage the data and develop tools to assist in operations and management of the system.

5.4 System Data Usage

As noted previously, the most desired feature of the system is material usage reporting. WSDOT felt the estimated material usage from the system would provide a reasonable baseline; however, WSDOT was not satisfied with the accuracy of the estimates. In addition to the use of material reports, AVL system data is also used primarily by WSDOT Maintenance Supervisors and Superintendents for vehicle location monitoring and situational awareness during winter storms. Maintenance Supervisors and Superintendents used the real-time data to monitor winter maintenance activities and make adjustments to resource allocation and route assignments.

The stored data is also used for material usage reporting and occasionally for post-event review/analysis as well as for review in the event of a tort claim of WSDOT liability in a traffic accident.

5.5 Agency Policy and Agreements for Data Sharing

WSDOT does not currently share data collected through the system with the general public or other agencies. WSDOT eventually would share the information with the public via a public-facing webpage.

6. System Implementation Process

6.1 Implementation Steps

WSDOT began testing AVL/GPS technology in selected areas around 2007 through a pilot project. Over time, WSDOT expanded the AVL system implementation to other Regions around 2010. Vendors providing WSDOT with AVL systems at the time included PreCise and Location Technologies. As noted previously, due to phase out of the 2G cellular network, WSDOT needed to upgrade the previously procured PreCise IX-302 AVL hardware. WSDOT saw this as an opportunity to not only procure and upgrade the existing AVL systems, but also establish a consistent approach with their AVL/GPS system on a statewide basis. As such, WSDOT developed and issued a solicitation in 2015 to procure a vendor to provide AVL hardware and software for all WSDOT snow plows, sweepers and emergency response vehicles throughout the state.

Knowing the potential challenges associated with the integration of the AVL system and spreader controllers from previous experience, WSDOT performed research in-house to gain a better understanding on the specifications of both the AVL systems and spreader controllers. WSDOT also worked with AVL vendors and spreader controller manufactures to confirm their research findings. The research helped WSDOT with smooth integration of the AVL system and spreader controllers. It also enabled WSDOT staff to correctly interpret data from the system and devices.

Location Technologies was awarded the contract and provided AVL hardware to WSDOT. WSDOT coordinated with local contractors within each of its six regions, who were already responsible for the up-fitting/assembly of WSDOT snow plows with spreader controllers and other on-board equipment, to perform the installation and integration of the AVL hardware per the recommended instructions from Location Technologies. These contractors also perform the required maintenance of the AVL system and coordinate with Location Technologies as needed for hardware repairs or replacements.

WSDOT developed a training program that was geared towards the ground level staff involved in operations (operators) and maintenance (mechanics/technicians). WSDOT also established a “Train the Trainer” program to ensure knowledge resided in each Region and many Areas. The Train the Trainer program helped build a network to share knowledge and best practice as well as support on-going operations and maintenance of the system. WSDOT conducted both formal and informal training to their maintenance staff. Formal training was conducted annually as part of WSDOT winter maintenance training. Staff from the WSDOT Technology Resource Center also traveled to Regions on a regular basis to provide refresher training as well as gather concerns and feedback.

6.2 Procurement Methods and Process

WSDOT’s solicitation only requested the vendor to provide AVL hardware and meet hardware and software specifications that were included. Location Technologies was selected through a review process, and they provided the requested quantities of AVL hardware to WSDOT within a short amount of time after being selected. Vendor demonstration was not included in the procurement. Instead, WSDOT relied on its prior experience with the pilots as well as peer exchange to gain knowledge on vendor qualifications from other states experience.

WSDOT noted that the procurement process was very smooth given the unique nature of how the State of Washington was able to purchase AVL equipment through the WSDOT Transportation Equipment Fund (TEF). The TEF is a state fund responsible for the acquisition, asset management, upkeep, and logistical support of the state’s 500 snow plow vehicles and the AVL/GPS system. The TEF is a revolving fund within WSDOT that provides vehicles and equipment to WSDOT programs so that they can accomplish their missions. For winter maintenance operations, the TEF program provides funding for snow plow vehicle support and AVL/GPS system maintenance through 35 equipment repair facilities and 130 fuel

stations across the six WSDOT Regions within the state.[2] WSDOT utilized funds within the TEF to procure the LT6 AVL system for the WSDOT snow plows.

6.3 Procurement Documents

The AVL/GPS system requirements included within the solicitation covered the following four aspects:

- General Specifications, listing the type of equipment and interfaces with existing operations desired,
- Hardware Specifications,
- GPS Receiver Specifications, and
- Optional Interfaces and Configurations

The specification requirements in the WSDOT AVL system solicitation are included in Appendix B.

7. System Benefits and Costs

7.1 Implementation Costs

A unit price of the equipment was requested from AVL hardware vendors as part of the solicitation process. Location Technologies reported on its unit price for AVL hardware, without the LT6 AVL antennae, as $615.00 per unit. WSDOT noted the costs of cellular communications were about half of what WSDOT was paying prior to the statewide procurement.

Additional costs for the implementation included system installation and integration costs, as well as WSDOT internal costs for training, GIS data management, and additional tool development. WSDOT didn't make cost information associated with those items available to the case study.

7.2 Costs for Operations and Maintenance

Location Technologies secured the cellular communications services and billed WSDOT monthly. The cost of cellular services was $5,677.20 monthly for 498 AVL units in 2017. Additional costs associated with operations and maintenance included operating costs for the WSDOT 700 MHz radio system, on-going maintenance of the system, and operations and maintenance of the WSDOT internal GIS database, interface and tools. The additional costs internal to WSDOT were not provided by WSDOT.

7.3 Benefits

One of the major benefits that WSDOT has observed with the AVL/GPS system was the overall savings in terms of tort liability. In the event that WSDOT snow plows are found to be at fault in a traffic incident with another vehicle or vehicles, WSDOT is entirely responsible for the financial coverage of vehicle repairs and other damages incurred from the incident regardless the amount of fault is attributed to the WSDOT snow plows. With the ability to provide detailed bread crumb trails on where and when WSDOT snow plows have traveled, this has significantly reduced the annual average of payments made by WSDOT resulting from tort claims. WSDOT paid an average of $2 million for winter maintenance related tort claims in the past. After the installation of the AVL system, the average payment went down to $500,000 per year.

Another benefit observed by WSDOT is the improved operational awareness of maintenance superintendents as they respond to winter storms. Maintenance Superintendents and Region

[2] Source: https://www.wsdot.wa.gov/Maintenance/Equipment/

Maintenance Engineers have used either the LT6 software interface and/or the in-house developed WSDOT interface for viewing vehicle locations and making operational adjustments based on situations. This in turns has improved WSDOT's winter maintenance operational efficiency.

8. System Issues and Challenges

8.1 Institutional Issues

Regarding the organizational structure of the WSDOT AVL program, the WSDOT Central Maintenance Office is responsible for managing maintenance funding and coordination with WSDOT Regions. However, the Central Office does not set policies and relies on Regions' buy-in to support the AVL program. As such, outreach to and buy-in from Regions is crucial to the success of the program. An added challenge to this de-centralized structure was the difficulty of achieving statewide consistency.

WSDOT noted that each of the 24 Maintenance Areas within the state determine their own respective maintenance priorities related to vehicle maintenance. This led to some Areas placing less of a priority on the installation and maintenance of the AVL system than other Areas. It also presented challenges to use of the system for gathering data on material usage and snow plow operations as well as for automated reporting. Leadership for some Areas was very engaged and pushed for quick AVL implementation. As a result, those Areas had the AVL system installed very quickly. Other WSDOT Areas have placed different priorities above that of properly installing and maintaining the AVL/GPS system, perhaps due to staffing and other vehicle repair issues that may be straining local resources.

WSDOT noted, as an example, the Regional Maintenance Engineer for Olympic Region sent out a memo to the maintenance staff within the region to communicate the use of the AVL/GPS system for winter maintenance was a high priority. This type of emphasis on the importance of properly using and maintaining the AVL system enables a higher confidence in the automated reporting of material usage coming out of the LT6 AVL system. In turn, this leads to improvements in the overall efficiency of material usage.

Buy-in from snow plow operators was still an issue for WSDOT. WSDOT experienced damages to the AVL hardware by operators intentionally. Some operators pulled the fuse to disable the system. Another concern was that the operators union wanted to limit WSDOT's ability to look into how operators performed their work. WSDOT focused on communicating positives of the system as a strategy to alleviate operators' concern. Key messages to facilitate operators buy-in included:

- The system is for tracking material usage not for tracking operators.
- The system data helps protect operators from tort claims.

WSDOT staff noted that operator concerns have lessened over time yet opposition still exists.

8.2 Technology Issues

WSDOT didn't experience issues related to the integration of Force America 5100 model spreader controllers with the LT6 AVL hardware. The spreader controllers worked well with polling requests from the LT6 AVL hardware. However, WSDOT vehicle technicians reported some issues with the integration of Force America 6100 model spreader controllers with the LT6 AVL hardware. WSDOT staff were unable to configure the data polling rate initially and this led a time-out issue with the communication of data from the spreader controller. WSDOT noted Force America was willing to work with them on the issue through a firmware upgrade to the controller which resolved the issue.

WSDOT also noted that air and pavement temperature sensors could provide faulty readings to the AVL equipment if the sensors were improperly installed or maintained. WSDOT mostly uses Vaisala temperature sensors and some RoadWatch sensors. The majority of the temperature sensors were tied into spreader controllers.

Integration of plow position sensors with the AVL system was another issue WSDOT experienced. WSDOT could not obtain accurate readings from plow position sensors on a consistent basis. WSDOT is working on identifying causes of the issue. WSDOT is also investigating the possibility of integrating plow hydraulic sensors with spreader controllers and using hydraulic sensors for plow position indicators.

From previous experience with the LT6 AVL system, the GPS antenna for LT6 AVL hardware would short out if it was not installed correctly. WSDOT has since standardized on a dual GPS / cellular antenna after experimenting with multiple types of antennae over the years. Figure 11 shows the mounting of the dual antenna on a WSDOT snow plow. The procurement of LT6 AVL system hardware in 2015 excluded the antennae from the manufacturer given the ability of WSDOT to provide the dual GPS / cellular antennae.

Figure 11. WSDOT Dual GPS / Cellular Antenna Location on Vehicle Roof

8.3 Procurement and Implementation Issues

8.3.1 Procurement Issues

As noted previously, the procurement process was very smooth given the unique nature of how the state was able to purchase AVL equipment through the WSDOT Transportation Equipment Fund (TEF). Location Technologies delivered the AVL hardware in a timely manner, allowing WSDOT to begin the installation shortly after the procurement.

8.3.2 Implementation Issues

WSDOT noted that one of the main challenges with the AVL hardware installation and wiring process was that there was no standard procedure followed in a consistent manner across WSDOT Regions, given that the information provided by Location Technologies did not include explicit wiring requirements. WSDOT needed to perform additional investigation on the specifications of the AVL device and spreader controllers to understand the wiring requirements. Once the wiring requirements were defined, the AVL hardware installation went through smoothly.

In addition, cables and connectors used to the AVL system installation might vary by type of trucks as well as type of spreader controllers. WSDOT noted Location Technologies was very helpful and worked with WSDOT to identify appropriate material needed for installation.

8.4 Operations and Maintenance Issues

WSDOT noted that a high staff turnover rate in some WSDOT Regions and Areas is a significant issue and is one of the reasons for keeping the operation of the AVL/GPS system as simple as possible. Training becomes very important to address the high rate of staff turnover. The main responsibility for WSDOT snow plow operators with respect to AVL operations is to monitor the power indicators on the AVL hardware within the vehicle before they begin their snow plow route, and to report on faulty hardware when detected. This reduces the amount of work to be performed by snow plow operators related to AVL operations and simplifies the overall operator training procedures.

9. Lessons Learned

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

- Agencies can benefit from pilot testing prior to full system deployment. Pilot testing helps agencies understand the technology and its limitations. It helps agencies gain knowledge on the system and identify potential issues may encounter during installation, integration, operations and maintenance. Experience and lessons learned from pilots also help develop a better project scope and specifications/requirements.
- Similarly, research on AVL systems and equipment desired to be integrated is extremely valuable. This includes obtaining experience from other agencies. Research helps agencies gain a better understanding on AVL systems and other equipment and how they could be integrated. Confirming research findings with vendors and manufacturers is also important.
- On-going training for both operations and maintenance is crucial to the success of an AVL program. Training should reach to the ground level staff involved in operations (operators) and maintenance (mechanics/technicians).
- A “train the trainer” program can ensure system knowledge resides within the agency. The train the trainer program also helps build a network to share knowledge and best practice as well as support on-going operations and maintenance of the system.
- Agency-owned radio communications systems can be a viable option to fill gaps in cellular communications.
- Buy-in and engagement from agency leadership is critical. It helps in establishing and procuring an AVL program. It also supports timely installation and maintenance as well as and encourages property use of the system.
- Positives of the system relevant to snow plow operators should be the focus when communicating with operators to promote buy-in.
- The AVL system can results in significant financial benefits to agencies as related to tort liability. This benefit can be translated as one of positive impacts to snow plow operators to promote their buy-in.

Appendix A WSDOT Survey Response

Name	Title	Agency	Phone	Email
Joe Schmit	Technology Resource Manager	Washington State DOT	360-705-7838	schmitj@wsdot.wa.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:			100% fleet implementation goal, with about 80% complete to date. Enhanced roadway surface condition sensors as well.	
3.Approximately how many vehicles are in your winter maintenance fleet?			500	
4.How many of your winter maintenance vehicles are equipped with AVL/GPS technology?			400	
5.Who is your contracted AVL / GPS vendor?			Location Technologies	
6.What modem / GPS brand(s) does your agency utilize?			LT6	
7. Who performed the installation of your AVL/GPS system? Was it the system vendor or DOT agency staff?			DOT Agency Staff	
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?			Yes	
If yes, please describe:				
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			Yes	
Air temperature sensor			Yes	
Humidity Sensor			No	
Dashcam			No	
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.			Vendors specifications do not always do what they state they do. It takes time to validate specs prior to implementing.	
12.What brand(s) of spreader controller does your agency use?			Force America, Dickey John, Parker, Raven, Schmidt	

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Data Management	
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	Not captured
Engine diagnostics	Not captured
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?	Vendor hosted SQL database and then copied to internal SQL database
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	No
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	No
Sharing of vehicle location through agency traveler information webpage	No
Road weather condition reporting	Yes
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?	No
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?	No
If yes, please describe what data is being shared with these other agencies.	Location, surface and air temp
19. Does your agency share AVL system data with the general public?	No

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Communications				
20. What type of communications does your AVL/GPS system use to transfer data? Please check all that apply.			Cellular network, Data radio system	
21. How would you rate the coverage of your communications system?			Covers most of maintenance areas with acceptable gaps	
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?			Web mapping and SQL reports, Excel	
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.			Monitoring application rates and aligning treatment goals	
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			Yes	
Installation & integration costs			Yes	
Costs associated with on-going operations (staffing, communications, software licensing, etc.)			No	
Maintenance costs			Yes	
Other costs, please describe				

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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	
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.			DOT's need to implement a sound training and support structure for AVL. Without an internal support network -- the program will have little traction and likely will not progress in a positive way.	
32. May we contact you with follow-up questions about your system(s)?			Yes	

Appendix B WSDOT AVL System Specification Requirements

Specification Requirements

Mobile Telematics GPS/AVL Modems			
	Specification Requirements Be sure to address each line below. Failure to do so may result in bid rejection	**Check** **If Meet or Exceed**	**Describe Offered Alternatives** **Note: Alternatives offered will be evaluated by subject matter experts. Alternatives offered that are not found to meet the specification requirements may cause the bid to be rejected.**
I.	**General:**		
1.	This specification is intended as a general indication of the type of equipment desired. Because of the variation in types of equipment available, other configurations will be evaluated and WSDOT reserves the right to reject any and all bids which do not meet the intent of the Specifications in the judgment of the Department. Bidders shall furnish complete specifications of the unit bid, including make and model numbers as well as all other pertinent data to facilitate evaluation for compliance with the intent of the specifications. *See the Specification Evaluation section of the RFQ.*	X	
2.	The WSDOT is soliciting bids for a mobile telematics GPS/AVL (automated vehicle locator) modem that meets or exceeds the following specifications. It is a requirement that the provided solution be supported by the vendor (hardware replacement/repair and phone troubleshooting) for a minimum of eight years for purchase date.	X	
3.	The solution must be able to interface with existing fleet operations. Specifically the telematics GPS/AVL modem must have the ability to receive and interpret the data stream from the following snow and ice controllers:	X	
	A. Force America SSC5100, 5100ex, 6100	X	
	B. Existing Parker, Raven, Dickey-John, Schmidt controllers	X	
	C. Ability to log and track front, wing, and/or belly plow status	X	
	D. Ability to log and track roadway weather temperature sensor units and onboard OBD-II/CAN bus data	X	
	E. Data must be consumable through common web service protocols, further detailed by WSDOT (end user).	X	

Mobile Telematics GPS/AVL Modems			
	Specification Requirements Be sure to address each line below. Failure to do so may result in bid rejection	**Check** **If Meet or Exceed**	**Describe Offered Alternatives** **Note: Alternatives offered will be evaluated by subject matter experts. Alternatives offered that are not found to meet the specification requirements may cause the bid to be rejected.**
II.	**Hardware:**		
1.	Size: Extruded Aluminum Case measuring approximately 5.5"x6"x1.5"	X	
2.	Power Requirements: 200mA at a 9-16VDC input operating range	X	
3.	GPS Antenna Options: Many options including trunklip, mag, and bulkhead.	X	
4.	Digital Inputs: 8 (Switch Closure)	X	
5.	Digital Outputs: 4 (May be reduced due to radio interface requirements)	X	
6.	Analog Inputs: 6 (May be reduced due to radio interface requirements)	X	
7.	Serial Interface: 2 RS-232	X	
8.	Available Baud Rates: Over the Air 1200 – 19.2KBd	X	
9.	Message Slotting: Up to 62.5 mSec	X	
III.	**GPS Receiver:**		
1.	SIRFIII Based. 20 parallel channels	X	
2.	Auto recovery while RTC crashes. 0.1 second reacquisition time.	X	
3.	SBAS (WAAS, EGNOS, MSAS) support. Enhanced algorithm for navigation stability.	X	
4.	NMEA-0183 compliant protocol/custom protocol.	X	
5.	Extremely fast TTFF at low signal levels.	X	
IV.	**Optional Interfaces and Configurations:**		
1.	Cellular Options: GSM/GPRS, CDMA Mobile Radio Interface	X	
2.	ZIGBEE/Spread Spectrum 802.11b/g (Wi-Fi), Bluetooth	X	
3.	Ethernet (with External Adapter) USB (with External Adapter)	X	