Expanded Use of AVL/GPS Technology

Final Report

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research for winter highway maintenance

AECOM Technical Services

Project 1044528/CR20-04
December 2022

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Expanded Use of AVL/GPS Technology

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16. Abstract

Summer road maintenance is a critical activity for highway maintenance agencies that involves a wide range of maintenance and construction vehicles that can be active at any given time, which makes vehicle and maintenance asset management challenges. Automated Vehicle Location (AVL) and Global Positioning Systems (GPS) technologies installed in winter maintenance vehicles have the potential to support summer road maintenance vehicles to improve asset tracking and management practices, as well as other purposes such as process automation and paperwork reduction for field staff in terms of activity reporting. The use of AVL/GPS systems to support both winter and summer maintenance activities can help justify the expenses incurred with respect to hardware / software acquisition and training costs across a wide range of applications.

This report continues building upon prior Clear Roads research and helps highway maintenance agencies optimize the value gained from the acquisition of AVL/GPS systems by deploying them year-round, rather than being limited to winter maintenance operations. This report summarizes agencies' experiences and lessons learned in using AVL/GPS technologies in summer and year-round maintenance activities. It also highlights the types of issues other highway maintenance agencies should consider prior to system procurement, provides guidance for successful transition and 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.

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Table of Contents

List of Figures

List of Tables

Executive Summary

The purpose of this research is to help highway maintenance agencies make more informed decisions to better implement Automated Vehicle Locator (AVL) / Global Positioning Systems (GPS) technology for year-round maintenance operations. The goal of this project is to continue building upon prior research and help highway maintenance agencies optimize the value gained from the acquisition of AVL/GPS systems by deploying them year-round, rather than being limited to winter maintenance operations.

While the main function of the technology is to provide automated vehicle location tracking for dispatchers and maintenance supervisors, AVL/GPS systems when integrated with in-vehicle equipment for non-winter maintenance operations can also provide valuable information about the status of maintenance operations, such as routes that have been swept, mileages of road stripes have been painted, amounts of paint or herbicide have been used, acreages of roadside have been mowed, etc. Furthermore, AVL/GPS systems can provide information about maintenance activities and potential roadway restrictions to the traveling public, either via roadside warning devices such as dynamic message signs (DMS) and warning beacons, through vehicle-to-infrastructure (V2I) communications, or directly to other connected vehicles via vehicle-to-vehicle (V2V) communications, to improve drivers' situational awareness and, in turn, traveler safety.

The research team surveyed multiple state departments of transportation (DOTs) and municipal highway maintenance agencies on the current state of AVL/GPS system usage for non-winter or year-round maintenance activities that include but are not limited to roadside mowing and vegetation control, street sweeping, and road stripe painting. From these survey responses, the research team selected five highway maintenance agencies (Alabama DOT, Illinois DOT, Missouri DOT, City of Farmington Hills and City of West Des Moines) to conduct detailed case studies. The case studies were performed through interviews with multiple levels of agency staff that have been involved in AVL/GPS system planning, procurement, implementation, management and operations.

Five stand-alone case study reports were developed based on the information gathered through interviews, along with additional input and documentation shared by interviewed agencies. Those case study reports collect and synthesize detailed information on varying levels of AVL/GPS implementation with respect to agencies' decision-making processes, implementation steps, issues and challenges, lessons learned, and costs and benefits. The case study reports summarize specific issues that are related to utilization of the AVL/GPS systems for non-winter maintenance operations. Lessons learned and recommendations derived from the case studies provide long-term support to agencies for initiating, ramping up, modifying and upgrading AVL/GPS implementation for non-winter or year-round maintenance operations.

In addition, the research team conducted abbreviated interviews with three additional agencies (Colorado DOT, Massachusetts DOT and New Hampshire DOT) for more focused interviews. Those interviews focused primarily on system implementation, data collection and utilization, and transferability of the system equipment between winter and non-winter maintenance vehicles.

This final report summarized the key results, findings and lessons learned from the case studies and additional interviews, along with literature review and agency surveys. It also identifies best practices and provides a series of recommendations for highway maintenance agencies to consider in the procurement, deployment and integration of an AVL/GPS system for non-winter or year-round maintenance operations. Key recommendations offered from this research include:

- Developing a clear communication message to both supervisors and operators on what the AVL/GPS system is and how the system helps increase the safety of maintenance operations.
- Educating staff about how the information gathered by the system is used is important. Providing vehicle operators access to the system to view how the information is used helps them to realize the benefits and minimize the "big brother" syndrome.
- Having a better understanding on the main features and capabilities of the systems that agencies are interested in prior to procurement allows for informed decision-making.
- Understaing agency needs with respect to winter and non-winter maintenance operations lead to better defined system requirements and specifications.
- Obtaining information and lessons learned from peer agencies provides ideas on how to improve implementation and utilization of AVL/GPS systems.
- Deciding upfront what data to collect and utilize helps to set realistic expectations.
- Working closely with the AVL/GPS vendors to develop customized reports and automated reporting that agencies desire is benefitical to agencies and helps to advance the AVL/GPS industry in supporting highway maintenance agencies.
- Having a champion who is knowledgeable and proactive in managing the AVL/GPS program is critical and can help resolve installation, integration, operations and maintenance issues.
- Starting small and gradually expanding system implementation and utilization over time can help alleviate issues. Agencies can start the deployment as a pilot project within a small area then expand the system to other areas once the concept is proven and buy-in/support is in place.
- Similarly, it is recommended to start with collecting a small, manageable amount of data at the beginning and plan to increase the amount of different data collected over time.
- It is beneficial to encourage staff to propose new use cases and applications of the AVL/GPS system. This can lead to new use cases of the system to support different types of non-winter maintenance activities.

1. Introduction

Summer road maintenance is a critical activity for highway maintenance agencies that includes roadway stripe painting and sweeping, roadside mowing and vegetation management, as well as the setup and operation of work zones along roadways for infrastructure repairs and maintenance such as curb, pavement and guardrail maintenance. These activities involve a wide range of maintenance and construction vehicles that can be active at any given time, which makes vehicle and maintenance asset management a challenge for state DOTs and roadway maintenance agencies.

Automated Vehicle Location (AVL) and Global Positioning Systems (GPS) technologies have been widely used by transportation agencies for winter maintenance and snow plow operations to monitor vehicle locations and equipment operational status among other purposes. AVL/GPS systems are generally comprised of hardware installed in the cab of the vehicle, vehicle-based communications equipment that facilitates data exchanges between vehicles and a central software system, and central software that allows for viewing and tracking of vehicle locations throughout a geographic region, among other information.

As these technologies have evolved over the past decade, maintenance agencies have explored the potential to utilize the same AVL/GPS hardware installed in winter maintenance vehicles for non-winter maintenance vehicles to improve asset tracking and management practices, as well as other purposes such as process automation and paperwork reduction for field staff in terms of activity reporting. The use of AVL/GPS systems to support both winter and non-winter maintenance activities can help justify the expenses incurred with respect to hardware/software acquisition and training costs across a wide range of applications.

1.1 Background

To help highway maintenance agencies make more informed decisions to better implement AVL/GPS technologies for year-round maintenance operations, the Clear Roads research program initiated this project (Clear Roads Project 20-04: Expanded Use of AVL/GPS Technology). The goal of this project is to continue building upon prior research and help highway maintenance agencies optimize the value gained from the acquisition of AVL/GPS systems by deploying them year-round, rather than being limited to winter maintenance operations. The final deliverables for the project will help fleet managers demonstrate the additional return on investment that can be realized through the use of these systems for year-round maintenance activities.

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 about the potential roadway restrictions to improve drivers' situational awareness and, in turn, traveler safety. Furthermore, AVL/GPS systems can be integrated with Connected Vehicle (CV) technology to communicate maintenance activities and roadway/lane restrictions, either via roadside warning devices such as dynamic message signs (DMS) and warning beacons, through vehicle-to-infrastructure (V2I) communications, or directly to other connected vehicles via vehicle-to-vehicle (V2V) communications.

The purpose of this report and its companion case study reports are to help other state DOTs make more informed decisions with respect to the implementation of AVL/GPS technology for non-winter maintenance activities. Those reports are intended to summarize agencies' experiences and lessons learned in using AVL/GPS technologies in summer and year-round maintenance activities. Those reports also highlight the types of issues other highway maintenance agencies should consider prior to system procurement, provides guidance for successful transition and 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.

1.2 Methodology

The research team utilized the following methodology to complete the project as described below.

1.2.1 Literature Review

The research team first completed a review of relevant literature and project documents to gain a better understanding of transportation agencies' AVL/GPS implementation and utilization experiences. This included a prior Clear Roads Project CR16-01: Utilization of AVL/GPS Technology – Case Studies, which collected survey information from agencies on their prior use of AVL/GPS systems for winter maintenance operations. The literature review performed by the research team is contained in Section 2 of this report.

1.2.2 Survey

In the fall of 2021, a survey was distributed to multiple state DOTs to gather basic, high-level information regarding each agency's AVL/GPS systems, as well as information on how those systems may be used to support non-winter maintenance activities. A similar, separate survey targeted to AVL/GPS manufacturers/vendors was conducted at the same time to gather their perspectives on using their systems for year-round activities related to not only transportation and roadway maintenance, but also other industries such as agriculture, aviation, construction, freight, and utility. The research team used the survey results to identify candidate agencies for in-depth interviews and case studies. A summary of the survey results and the analysis performed by the research team is contained in Section 3 of this report.

1.2.3 Interviews and Case Studies

Virtual interviews were conducted with staff from each of the case study agencies to gain a detailed understanding on how their AVL/GPS systems supported year-round maintenance activities. Interviews were conducted between January 2022 and March 2022 with the five agencies selected through the project survey. Interview summaries for each agency are contained in the Appendices B through F of this report.

With the information gathered from these interviews, the research team developed individual case study reports documenting how each agency implements and utilizes their AVL/GPS system for year-round highway maintenance activities. A summary of the case studies is contained in Section 4 of this report. Full versions of the case study reports are published separately on the Clear Roads Program website (http://clearroads.org/).

The research team also interviewed three additional agencies to gather information to supplement the insights obtained through the five case studies. Those three agencies were the New Hampshire DOT, Massachusetts DOT, and Colorado DOT. Two of the DOTs – New Hampshire and Massachusetts – performed transfers of AVL/GPS equipment between winter and non-winter maintenance vehicles. Interviews with those agencies were intended to obtain specific insights on their goals, implementation and operations regarding equipment transfers. Findings of those three interviews are summarized in Section 4 of this report.

1.2.4 Best Practices and Recommendations

Recommendations were developed to summarize the key takeaways from the interviews and case studies. In addition, best practices were also identified and highlighted. The recommendations as well as best practices from the interviews and case studies are included in Section 5 of this report.

2. Literature Review

The Literature Review section provides an overview of key literature related to the implementation of AVL/GPS systems for non-winter maintenance operations. The list of literature reviewed included documents recommended by the Clear Roads project subcommittee and additional literature identified and reviewed by the research team. The research team conducted a literature search and reviewed agency (in particular Federal Highway Administration) publications, conference papers, presentations and proceedings, and professional and trade journals. The purpose of the review was to identify and gain a better understanding of transportation agencies' non-winter maintenance operations utilizing AVL/GPS systems. Typically, the focus of AVL/GPS technology within transportation agencies is on winter maintenance activities since there is a high potential for savings on material and vehicle/equipment uses and staffing resources. The project team was able to filter through these studies to identify literature with non-winter maintenance operations. A summary of the literature search is presented in the following paragraphs.

An Innovative Approach to Smarter Mowing, Utilizing Automated Vehicle Location to Enhance Mowing Operations

The Minnesota Department of Transportation (MnDOT) conducted a study to investigate utilizing AVL systems to optimize mowing practices at the DOT. Typically, AVL systems are acquired for winter maintenance activities; however, there was a desire to see if the same hardware and software could be used on the mowing equipment to realize benefits in terms of cost savings in roadside mowing operations.

In 2015 and 2016, MnDOT installed 30 mowers in the Metro District with an AVL system (Ameritrak systems). This study focused on the following tasks:

- Develop best practices for the installation, training, and maintenance of the AVL systems;
- Automation of the mowing paperwork for operators;
- Ease of supervision during mowing operations;
- Improvement on tracking mowing needs and determining a level of service;
- Reduction in the spread of noxious weeds and the use of herbicide along MnDOT roadways; and
- Optimization of mower routes.

Prior to the AVL system installation, the mowing practices consisted of paper map books of areas with noxious weeds for the operators to avoid, which requires additional attention from operators during mowing, causing these weeds to be mowed over frequently. Additionally, the operators were responsible for tracking reference points in order to calculate acres mowed. With an AVL system, MnDOT hoped to automate these tasks to provide accurate real-time data and reduce the operators' responsibility, thereby allowing operators to focus on the mower deck and traffic.

MnDOT worked with the AVL vendor to develop software and digitalize the known mowing data. Then the system was installed in the mowers which included an onboard mapping screen to show operators where noxious weeds were documented. In addition, system reports and a training program were developed.

The system was able to generate the completion reports for the mowing operations. Though the pilot study had many successes, one lesson learned was the complexity and effort of the software development for this application was more than initially anticipated. Overall, this project had a one-time cost of $110,000 (not including staff time) and an on-going annual cost of $11,000 for operations and maintenance. It will take more than one season of data to discover all and accurate benefits for this AVL application. However, this is the most comprehensive study for non-winter related operations for transportation agencies.

Benefit-Cost Assessment of Automatic Vehicle Location (AVL) in Highway Maintenance

Eric Meyer and Ishtiaque Ahmed from the University of Kansas reviewed the benefit-cost of AVL systems implemented for highway maintenance at the request of Kansas Department of Transportation (KDOT) in 2000. Winter maintenance operations were a part of this study, but the authors included other highway maintenance operations within the analysis.

This study started with a survey of highway maintenance AVL users, which provided base parameters for the benefit-cost analysis. Two risk perspectives were reviewed to provide a lower limit to very high limit of results. The low risk perspective used all conservative assumptions, representing the minimum benefits limit; while the high risk perspective used less conservative assumptions to represent the upper benefit limits one may realize. Overall, the benefits for any given user should fall with the range developed in this analysis.

The data gathered from the survey were used to determine the benefit-cost ratio. The cost assessment reviewed investment costs and operations and maintenance costs. Some of the benefits not related to winter maintenance activities were observed, including:

- More timely responses to emergencies;
- Reduced legal costs from tort claims allegedly involving KDOT maintenance vehicles;
- Reduced time with routine paperwork;
- Enhanced locational accuracy of various inventories and map segments;
- Near real-time traveling information;
- Improved efficiency and effectiveness of roadside maintenance; and
- Reduced fleet maintenance cost due to improved fleet management.

A 20-year life cycle was reviewed in this analysis. The overall benefit-cost estimates from this research are:

- Savings in paperwork – moderate estimate of 15% time savings, resulting in $67,908 to $101,862 per year;
- Savings from more efficient fleet management – between 5-20% savings resulting in $398,864 to $1,595,455 in savings. For painting trucks, the savings would be between $17,336 to $69,344.

This report also reviewed savings from crashes; however, it was directly related to winter maintenance operations.

Automated Vehicle Location (AVL) For Road Condition Reporting

The Indiana DOT (INDOT) reviewed utilizing the AVL systems in road conditions reporting. Road condition data were fed into INDOT's Maintenance Decision Support System (MDSS) to assist managers in efficiently treating the roadways for winter maintenance operations. This report also included a section that reviewed the use of AVL for summer applications. These summer AVL activities focused on painting operations.

Over the 2007 summer season, a paint striping application using the AVL technology was developed and tested in the Laporte District. Operators would input via a touchscreen laptop the type of stripes being painted, i.e. white skip line, yellow single solid line, yellow double solid, etc. The program recorded the type and location of paint stripes, automatically calculated the total linear footage of stripe, and displayed location information on a map.

The report noted that the AVL units were interfaced with MDSS that allowed the viewing of weather radar. This could be helpful to maintenance crews that are working on activities affected by weather, as they could choose to continue working or stop based on the weather radar images. The report noted that INDOT desired to expand the AVL systems to other non-winter maintenance activities for automated reporting. Those activities include:

- Chip Sealing;
- Crack Sealing;
- Work Management System Reports Interface;
- Mowing;
- Herbicide; and
- Bridge Repair.

The study focused primarily on the winter maintenance activities. Overall, the project was a success and the authors stated that the AVL systems could be beneficial and should be considered for summer activities.

Using Automatic Vehicle Location (AVL) for Real-time Maintenance Identification and Tracking

Work Zone Data Exchange (WZDx) provides standard protocol to push an agency's work zone data to third party users. This requires constant communication and any changes to operations could not be reported

quick enough to post to these third party users. Therefore, this study tested using AVL data to detect work zones, which then could be automatically sent to WZDx. Iowa data were utilized for this study.

An algorithm reviews average truck speeds clusters compared to the posted speed limits, to indicate the potential work zone. This algorithm was considered successful and is a great first-step in automating in real-time, accurate work zone data to the proper stakeholders.

Utilization of AVL/GPS Technology: Case Studies

The Clear Roads "Utilization of AVL/GPS Technology: Case Studies" focused on the use of AVL/GPS technology for winter maintenance, not summer activities; however, the same study framework applied to the Clear Roads "Expanded Use of AVL/GPS Technology" study.

The "Utilization of AVL/GPS Technology: Case Studies" began with a similar literature review with studies related to winter maintenance applications of AVL/GPS technology. The study then developed a comprehensive survey that covered the following topics:

- Planning and Decision Making;
- Procurement;
- System Implementation;
- Data Collection and Utilization; and
- Operations and Maintenance.

The survey results allowed the project team to select six agencies to conduct in-depth interviews on their use of AVL/GPS systems and then develop a case study summary for each agency. The final report presents the literature review summary, the survey summary, the in-depth case study summaries, and best practices and recommendations based on the study's findings.

One of the questions in the survey asked agencies the following question: *Does your agency move your AVL/GPS vehicle units to different trucks or equipment for use during summer maintenance operations?*

Three agencies answered "Yes" to this question: New York State DOT, Missouri DOT, and Pennsylvania DOT. There may be more agencies that utilize AVL during summer maintenance but do not move the units. However, these three agencies may provide unique insights into the use for AVL systems for summer maintenance.

Farming and Agriculture GPS Fleet Tracking

GPS technology has been utilized in farming for several decades. Precision farming has advanced particularly in the past two decades with great increases in the efficiency and production of farming and agriculture products. According to a 2017 study conducted in Southern US with cotton producers, the adoption level of GPS technology was 67%. GPS along with other precision farming technology has a positive impact on increasing farm output and creating sustainable agriculture around the world.

The most common uses of GPS technology in agriculture are for yield mapping and variable rate fertilizer/pesticide applications. Both have relevance to highway maintenance operations, particularly mowing operations and vegetation management.

Verizon connect published an article that discusses how the farming and agriculture industry have utilized GPS technology. This industry installs GPS technology on plows, tractors, combines, etc. This technology improves efficiency as the demand to yield more product with less resources. There are three ways this efficiency is realized:

- Tracking of farm equipment, which protects assets and increases worker productivity. This is achieved by GPS tracking devices and fleet management solutions, making it easier to identify where vehicles are left after each shift and to track the location of where these assets were throughout the day.
- Use of geofencing for cultivation through fertilization and harvesting. These geofences can alert when assets are in areas they shouldn't be and allows managers to quickly correct the situation. These geofences can prioritize target areas for fertilizing and harvesting, fence off regions that should be left alone, isolate land where farm animals may be grazing to prevent injury to humans and livestock, and identify location that have, should have, or shouldn't be treated with pesticides.
- Improve farm vehicle routes to drive efficiencies and save costs. GPS tracking improves routes with near real-time monitoring of the field services workers.

The most common uses of GPS technology in agriculture are for yield mapping and variable rate fertilizer/pesticide applications. Both have relevance to highway maintenance operations, particularly mowing operations and vegetation management.

Other Relevant Study

The Ohio DOT GPS/AVL study (2017) conducted a survey asking agencies: *Are there other phases of the [GPS/AVL] project already emplaced? What do these other phases consist of?*

Michigan DOT responded that they were testing a pilot study on using GPS/AVL system for herbicide spraying trucks used in the summer. The research team was unable to find a publication of this study but intended to gather additional information from Michigan DOT through the survey.

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3. Survey Summary

3.1 Background Information

Section 3 provides a summary of the responses received from surveys on the use of AVL/GPS systems for year-round maintenance operations from various highway maintenance agencies and AVL/GPS manufacturers and vendors. It also presents recommendations on selecting agencies for further in-depth interviews to gather more information on how those systems can support year-round maintenance activities.

Two surveys were developed: a survey targeted to highway maintenance agencies and another survey targeted to AVL/GPS system manufacturers and vendors. The survey for highway maintenance agencies was designed to gather basic, high-level information regarding each agency's AVL/GPS systems, as well as detailed information on how those systems may be used to support non-winter maintenance activities. The survey targeted to AVL/GPS manufacturers/vendors was designed to gather their perspectives on using their systems for year-round activities related to not only transportation and roadway maintenance, but also other industries such as agriculture, aviation, construction, freight, and utility.

The surveys were made available to responders in an online format. The survey for AVL/GPS manufacturers/ vendors was sent via email to a listing of vendor contacts obtained through research prior to the survey distribution. Highway maintenance agency surveys were distributed through the following methods:

- Snow and Ice listserv maintained by the University of Iowa
- Clear Roads member state DOTs
- American Public Works Association (APWA)
- The AASHTO Equipment Management Technical Services Program (EMTSP) membership
- The AASHTO Committee on Maintenance
- International agencies through the Norwegian Public Roads Administration and other Nordic countries through the Nordic Road Association (NVF)

A total of 52 responses to the highway maintenance agency survey were collected. Table 1 presents a listing of the agencies that responded to the survey that have AVL/GPS systems arranged by season of maintenance. Table 2 presents a summary of agencies that responded to the survey without AVL/GPS systems. A question-by-question summary of the responses received from the responding agencies is presented in Section 3.2.

Table 1. Highway Maintenance Agency Survey Respondents with AVL/GPS Systems

Survey Respondents with AVL/GPS Systems for Winter Maintenance Only			
Agency	**Representative**	**Agency**	**Representative**
Montana DOT	Doug McBroom	City of Lee's Summit, MO	Mark Stinson
Nebraska DOT	Michael Mattison and Tom Renninger	Road Commission for Oakland County, MI	Darryl Heid
North Dakota DOT	Brandon Beise	City of Shawnee, KS	Doug Whitacre
Ohio DOT	Scott Lucas	Tennessee DOT	Doug Tarwater
South Dakota DOT	Danny Varilek	Oklahoma DOT	Taylor Henderson
Vermont Agency of Transportation	Todd Law	Wisconsin DOT	Michael Adams
Survey Respondents with AVL/GPS Systems For Non-Winter Maintenance Only			
Prince William County Service Authority, VA	David Jenkins	Alabama DOT	Kerry NeSmith
Survey Respondents with AVL/GPS Systems for Both Winter and Non-Winter Maintenance			
Utah DOT	Kendall Draney and Rhett Arnell	Agency for Urban Environment, City of Oslo	Joakim Hjertum
Michigan DOT	Justin Droste	City of Bozeman, MT	John Van Delinder
Delaware DOT	Alastair Probert	City of Dublin, OH	Gary Browning
Idaho Transportation Department	Steve Spoor / Kelley Dick	Regional Municipality of Niagara, Canada	Derek McGaghey
Illinois DOT	Randy Neal	City of Iowa City, IA	Ronald R Knoche
Iowa DOT	Craig Bargfrede	City of St. John's, Canada	David Crowe
Maryland DOT State Highway Administration	Tim Lawler	East End Crossing Partners (KY-OH-IN)	Phillip Anderle
Massachusetts DOT	Mark A Goldstein	City of West Des Moines, IA	Bret Hodne
Colorado DOT	Howard Ray / John Lorme	Norwegian Public Roads Administration	Bård Nonstad
Minnesota DOT	Joe Huneke / Chase Fester	City of Farmington Hills, MI	Bryan Pickworth
Oregon DOT	Chas Van Genderen	Town of Lexington, MA	Marc Valenti
Pennsylvania DOT	Dan Whetzel	Village of Algonquin, IL	Michael Reif and Vincent Kilcullen
Rhode Island DOT	Joseph A Bucci	Virginia DOT	Joseph R. Williams
Texas DOT	Troy Simmons	Washington State DOT	James R Morin
Arizona DOT	Kevin Duby	New Hampshire DOT	David Gray
Missouri DOT	Paul Denkler		

Table 2. Highway Maintenance Agency Survey Respondents without AVL/GPS Systems

Agency	Representative	Agency	Representative
Kansas DOT	Clay Adams / Jaci Vogel	West Virginia Dept. of Highways	Jeff Pifer
Maine DOT	Brian Burne	Caltrans	Jeremy Matsuo
City of Newcastle, WA	Jeff Brauns	New Mexico DOT	John Romero

A total of four responses to the survey for AVL/GPS manufacturers/vendors were received. Section 3.3 contains a question-by-question summary of the responses received from the AVL/GPS system vendors that responded to the survey.

3.2 Summary of Highway Maintenance Agency Survey Responses

The survey for highway maintenance agencies consisted of 21 questions organized into the following four parts:

- Part A – Questions on the extent of AVL/GPS implementation by agencies for winter and non-winter maintenance activities.
- Part B – Questions on how AVL/GPS system data is captured from vehicle equipment and how that data is utilized and shared by agencies in performing winter and non-winter maintenance activities.
- Part C – Questions on how the AVL/GPS System is operated and maintained by the agency, including whether any available cost and benefit information is available.
- Part D – Questions on lessons learned that the agencies would like to share and whether follow-up questions on the AVL/GPS system could be requested.

3.2.1 Part A: Basic Information on AVL/GPS System

The first part of the survey contained five questions to help understand the extent of the AVL/GPS implementation by various agencies for winter and non-winter maintenance. While there was a total of 52 responses, seven agencies indicated they had no AVL/GPS system installed currently. Therefore, a total of 45 maintenance agencies responded positively that they had implemented AVL/GPS systems for winter and/or non-winter maintenance activities.

Question 1. Do you currently use AVL/GPS technology for maintenance operations? (Select all that apply)

Winter maintenance (i.e. snow plows)	Non-winter maintenance	No, but we are considering AVL/GPS on maintenance vehicles or equipment	No, do not have AVL/GPS on maintenance vehicles or equipment
43	33	4	3

Question 2. Please provide the names of your AVL/GPS vendor(s) for the following types of maintenance operations.

Winter Maintenance		Non-winter Maintenance	
AVL/GPS Vendor	**Number of Agencies**	**AVL/GPS Vendor**	**Number of Agencies**
GeoTab	10	Verizon NetworkFleet	7
Parsons	4	Geotab	7
PreCise	4	PreCise MRM	3
Location Technologies	3	Cypress	2
Verizon NetworkFleet	3	Skyhawk Telematics	2
Cypress	2	Trimble	2
Skyhawk Telematics	2	Air Automotive Tracking	1
Zeekit	2	CalAmp	1
Air Automotive Tracking	1	Zonar	1
Ameritrak Fleet Solutions	1	Fleet Complete	1
CalAmp	1	Ligo	1
Certified Power Solutions	1	Motorola,CompassCom, Neotreks	1
Ligo	1	Location Technologies	1
Motorola,CompassCom, Neotreks	1	US Fleet Tracking	1
Oak Knot Holdings	1	Zeekit	1
ODOT & Oklahoma University	1	Zonar	1
ROADA	1		
Samsara	1		
Zonar	1		

Question 3. What types of non-winter maintenance vehicles/equipment does your agency use AVL/GPS units with and their approximate quantities?

Types of Vehicles / Equipment	None	Less than 20	21 to 50	51 to 100	101 to 300	301 to 500	More than 500
Mowers	14	12	3	1	2	0	1
Paint trucks	14	17	2	0	0	0	0
Street Sweepers	10	18	3	0	0	1	0
Jetter Trucks	20	11	0	0	0	0	0
Light-weight vehicles	7	5	7	1	5	6	3
Tanker trucks (for non-winter maintenance)	17	12	3	0	0	0	0
Pesticide sprayer vehicles	26	5	1	0	0	0	0

Types of Vehicles / Equipment	None	Less than 20	21 to 50	51 to 100	101 to 300	301 to 500	More than 500
Temporary work zone / roadway maintenance equipment and vehicles	16	5	3	2	2	0	4
Other (please specify the respective type(s) (see below)	12	4	1	1	0	0	2

Other vehicles/equipment not listed:

Agency	Quantity	Types of Equipment
Missouri DOT	21 to 50	Tractors, skid steers, loaders, backhoes, aerial units, drills
Illinois DOT	More than 500	Plow truck when used for traffic control - answered temp work zones with emergency vehicles; deployable pumps
Massachusetts DOT	Less than 20	Litter Patrols
Michigan DOT	Less than 20	Herbicide sprayer vehicles
Norwegian Public Roads Administration	Less than 20	Location of guard rails, machine control for road construction (graders, excavators). NPRA are only a client.
Oregon DOT	21 to 50	For non-winter use, we use AVL from several vendors on various vehicles to monitor our fleet for location/safety as well as some striping applications.
Pennsylvania DOT	More than 500	We have AVL in all of our plow trucks that go out and do summer maintenance activities. over 2,500 units
Regional Municipality of Niagara, Canada	Less than 20	Radar speed trailers

Question 4. Does your agency move your AVL/GPS vehicle units from winter maintenance vehicles to different trucks or equipment for use during non-winter maintenance operations?

Yes	No
3	42

3.2.2 Part B: AVL/GPS System Data Collection

The second part of the survey contained eight questions to help understand the level of integration between the AVL/GPS System and other winter and non-winter maintenance vehicle equipment.

Question 1. Is your AVL/ GPS system integrated with other systems or equipment on vehicles used for non-winter maintenance operations?

Yes	No	No response

17	26	2

If yes, what types of equipment is the AVL/GPS system integrated with?

Agency	**Types of Equipment**
Colorado DOT	Vehicle maintenance or servicing and location services
Prince William County Service Authority, VA	Cityworks Software
City of St. John's, Canada	Dash cams, fleet maintenance
Illinois DOT	Emergency response vehicles to not car pick-up and paint trucks with carriage down
Michigan DOT	engine port
Alabama DOT	Herbicide spray vehicles
Washington State DOT	Hydraulic system switches to monitor position of broom, blade etc.
City of Farmington Hills, MI	Motor Graders, Gradalls (Excavators)
East End Crossing Partners	OBDI onboard diagnostics and MDSS
Oregon DOT	ODOT has 5 Striping trucks from Skip-Line which provides all AVL in concert with material mgt functionality for those trucks which manages paint application, reflective bead loads, interval and spacing. Here is URL: https://skipline.com/software-features/
City of Dublin, OH	our Snow reporting application
Montana DOT	plow camera
Rhode Island DOT	PTO functions
City of West Des Moines, IA	Sensors to indicate vehicle operations.
Minnesota DOT	We have integrated them into our roadside dynamic message boards when crews are working within a 1-mile area of the sign
New Hampshire DOT	We have them on street sweepers
Missouri DOT	Cameras & HAAS Alert for sending early alerts to Waze app.

Question 2. What types of data do AVL/GPS units collect for non-winter maintenance activities? (Select all that apply)

Types of AVL/GPS Data Collected	**Number of Agencies Reporting Data**
Location information with lat-long coordinates	39

Types of AVL/GPS Data Collected	Number of Agencies Reporting Data
Task-based information	16
Material application data	14
Dash-cam video	6
Other (please specify):	6
Engine run hours	1
Only applies to Telematics on Light Duty Vehicles	1
speed, activity (or lack thereof: stationary time)	1
travel speed, starts/stops with duration, idle time, diagnostics	1
Vehicle diagnostics	1
All at-risk driving behavior such as speeding, seat belts unbuckled, backing on departure, harsh corning, harsh braking and possible collision	1

Question 3. Does your AVL/GPS system report data to a central software in or near real time, or is the data reported after a delay?

Delayed reporting	In or near real-time	No response
7	37	1

Question 4. What communications method do you use for the AVL/GPS equipment? (Select all that apply)?

Type of Communications Method	Number of Agencies
Cellular modem communications to central software	38
Data radio system	3
Wi-Fi-based data communications at garage	5
Other (please specify):	2
On board mi-fi system	1

Question 5. What modem/GPS brand(s) does your agency utilize?

Modem/GPS Brand	Count of Vendors Reported
Verizon	7
GeoTab	7
AT&T	3
CTM-200 CTM-One	3
Sierra Wireless	2
Telit	2

Modem/GPS Brand	Count of Vendors Reported
CalAmp	1
Atrack AK11 and AX9	1
Dell Gateway	1
Location Technologies	1
Motorola radios	1
Huawei	1
Peplink	1
Precise	1
Samsara	1
Trimble	1

Question 6. How does your agency use the data collected by AVL/GPS equipment? (Select all that apply)

Type of Data Usage	Number of Agencies Reported
Tort claims	31
Maintenance operations planning	29
Monitor and improve shop or field activities	28
Public information (i.e. inform the public regarding the locations of maintenance activities)	21
Process automation	11
Paperwork reduction	11
Environmental documentation (such as MS4 paperwork for street sweeping)	9
Other (please specify)	7
Addressing complaints by public on poor driving	1
Documentation of snow and ice activities, 511, and Salt Sustainability measures determined from MDSS recommendations compared to usage.	1
Documentation of work	1
Quality control	1
Routing and keeping track of finished routes during snow operations	1
Safety, checking on mowing crews and seasonals	1
Winter Maintenance reporting and MDSS	1
Proactive driver safety program to minimize the potential for injury and keep maintenance and liability costs low.	1

Question 7. Does your agency share AVL/GPS system data collected during winter and/or non-winter maintenance operations with the general public?

Yes	No	No response
20	24	1

Question 8. If you answered "Yes" to the previous question, please describe what AVL/GPS system data is shared with the general public.

Winter Maintenance Information	Non-Winter Maintenance Information
Plow location	Location
Plow location on our public 511 sites	Direction of travel
Plow locations and routes	Camera image of road ahead of truck
Delayed location of plow trucks	
Direction of travel	
Camera images of road ahead of truck	
During level 3 events the public can see a map of vehicle locations	
Roadway serviced times	
Road condition reporting from MDSS to 511	
Amount of road chemicals used during the winter season	
When a street was plowed or graded.	

3.2.3 Part C: AVL/GPS System Operations and Maintenance

The third part of the survey contained seven questions to help understand how the AVL/GPS System data is captured from vehicle equipment and how that data is utilized and shared by the agencies in performing winter and non-winter maintenance activities.

Question 1. Does your agency use the AVL/GPS system data for analyses to improve upon agency operations?

Yes	No	No response
32	11	2

If yes, please describe how the data is used by your agency (e.g. performance reporting).

Agency	Data Usage for Improving Operations
Agency for Urban Environment, City of Oslo	To pinpoint controls
Alabama DOT	For herbicide operations currently deploying a pilot installation to determine if features are providing desired information.
City of Bozeman MT	Snow routes.
City of Farmington Hills, MI	Use pavement temps for better decision making, and track progress of summer storm cleanup and plow progress to name a few
City of Lee's Summit, MO	Route optimization
City of West Des Moines, IA	Efficiency and routing
Colorado DOT	Used to right size the fleet and produce vehicle service work orders.
Delaware DOT	Look for issues with snow plow trucks being inefficient during storm operations
Idaho Transportation Department	For Winter only, we use the data to compare actual level of effort and materials applied to standards in an effort to improve efficiency.
Illinois DOT	Efficiency in deicing. Staff management.
Iowa DOT	Material Usage data, vehicle data- speed primarily,
Massachusetts DOT	We use it at the depot/shop level to indicate whether plow routes have been tended recently enough with respect to ongoing precipitation rate/weather conditions
Minnesota DOT	Data collected from AVL is sent to MDSS application, from there road condition data is shared with 511 application. De-icing chemical usage is analyzed against MDSS recommended for each route in the MnDOT system. That is then used for a salt reduction measure calculated by MDSS. We track idle time and operator speed in our light duty fleet. We utilize them in our snow and ice fleet to assist with MDSS recommendations that are route based.
Missouri DOT	Tort claims, vehicle maintenance records, automated reporting of mileage and engine hours, fuel efficiencies (reduce idling), Increase drive safety with driver scorecards based on AVL/GPS data
Nebraska DOT	We use it with MDSS to provide maintenance recommendations to operators via a touchscreen display during winter storm events. Reporting of deicing material usage and speed while applying.
North Dakota DOT	This is goal, but the limited deployment hinders wide-spread analysis.
Ohio DOT	We are able to see areas that are missed and we know how much deicer is placed in various locations.
Oklahoma DOT	Improve our snow removal operations. Make sure state vehicles are used properly.

Agency	Data Usage for Improving Operations
Oregon DOT	Oregon is just developing its AVL mgt systems. We do use the tech to monitor light fleet utilization as part of analyze need and supporting decision making. We use AVL integrated with other software to support striping operations and defend against Tort claims and monitor vehicle location for employee safety. As the program matures these activities will develop further.
Pennsylvania DOT	we utilize the data to assist in teaching operators about lower material usage.
Prince William County Service Authority, VA (PWCSA)	Performance measures, Mileage Reports, etc.
Rhode Island DOT	Efficiency improvements, performance metrics
Road Commission for Oakland County, MI	If an issue comes up, the route can be reviewed to see what happened.
South Dakota DOT	We use the data for performance reporting, training and post storm reviews. We look for trouble area's - where it takes more chemicals to keep the road open. Our Project Development team will review the data and see if these trouble areas can be fixed during a construction project. We also will use the data for snow fence placement if construction can't be done.
Tennessee DOT	Snow route review
Texas DOT	GPS/AVL data is used to analyze the effectiveness of day to day and emergency support operations.
Utah DOT	Trying to use to optimize plow routes
Vermont Agency of Transportation	Validate application rates and provides chloride use in impaired waterways.
Village of Algonquin, IL	For the planning of snow plow routes; Better routing, and faster response to calls for service by sending the closest unit
Virginia DOT	Performance reporting, performance planning, route efficiencies, contractor payment auditing
Washington State DOT	Currently this primarily applies to winter maintenance. We use AVL/GPS data to monitor spread rate, vehicle speed, pre-wet condition and temp. Seed and spread rate are monitored by supervisors and managers to ensure proper application. Incident Response Vehicles are also equipped with AVL/GPS, this data is used to monitor response time and position for Traffic Management Center awareness and strategic placement of resources.
Wisconsin DOT	Mainly winter ops. We use salt data to try to pinpoint areas of improvement.

Question 2. Where types of AVL/GPS software does your agency utilize? (Select all that apply)

Software developed by agency	AVL/GPS vendor software	Third party software
7	38	8

Question 3. Does your agency handle AVL/GPS data storage and management with agency staff, or is this managed with a maintenance contract with the AVL/GPS system provider, or other third-party entity? (Select all that apply)

Agency staff	AVL/GPS provider	Third party (consultant, university, etc.)
9	38	6

Question 4. If the AVL/GPS equipment is transferable between winter and non-winter maintenance vehicles/equipment, has your agency developed any mechanical configurations to guide the equipment transfer activity?

Yes	No	Not Applicable	No response
1	6	36	2

Question 5. Has your agency measured the time and cost associated with AVL/GPS equipment transfer activities?

Yes	No	Not Applicable	No response
0	9	35	1

Question 6. Has your agency measured quantifiable benefits of implementing AVL/GPS for year-round maintenance uses?

Yes	No	No response
7	36	2

Question 7. Has your agency deployed or considered deploying connected vehicle technology on non-winter maintenance vehicles or equipment?

Yes, we are considering	Yes, we have tested/deployed	No	No response
13	7	22	3

3.2.4 Part D: Deployment Experience

The final part of the survey contained the following two questions to gather lessons learned that the agencies would like to share in the survey and determine whether or not follow-up questions on the AVL/GPS system could be requested.

Question 1. What practical advice can be offered to others interested in implementing AVL/GPS technology for both winter and non-winter maintenance operations?

Agency	General Lessons Learned
Agency for Urban Environment, City of Oslo	Be clear on what you will use data for. Make a step by step plan for what kind of operations you need first, second and so on, do not take it all at once
City of Bozeman MT	Snow plowing and residential street plowing (which we use motor graders), we are able to tell citizens when they will be or were on their streets. Saved us several times when a parked car gets damaged and they automatically assume it was done by a plow. We can prove we weren't there.
City of Farmington Hills, MI	Have tested portable units on sweeper contractor.
City of Iowa City, IA	Remind staff that this is for safety.
City of West Des Moines, IA	Provide access to the systems to operators so they can realize the benefits and minimize the "big brother" syndrome. Educate staff about how the information will be utilized. Decide upfront what data you will want to collect and utilize for your respective agency. Too much data can create overload. Have a champion to manage the program. You will run into issues, so an agency needs to have someone knowledgeable and pro-active in working to alleviate issues.
Colorado DOT	Know what you want to achieve with the technology before implementing it. Gain support from leadership. Use the principles of change management. Our entire fleet is AVL'd, it has help us recover stolen vehicles and hold employee accountable when employees abuse the asset. Additionally, we have been able to dis-prove damage claims from the public.
Delaware DOT	Need to ensure that equipment is installed correctly and that someone is following up routinely to make sure all of the devices are communicating correctly
East End Crossing Partners	AVL is really a scalable initiative. Make sure going in that your vendor can handle your fleet and your needs and make sure the information you need is already available in your solution otherwise you will waste time and money trying to get your vendor to create something for you.
Idaho Transportation Department	Know what business problem you are trying to solve before implementing. Just adding AVL/GPS and then seeing what you can do with the data never results in a system that serves a purpose.
Illinois DOT	Start slow and build out. Utilize areas that are supportive of the technology before moving out to more hesitant areas.
Iowa DOT	Before implementing GPS/AVL the organization needs to have a solid understanding what data you want collected and then how that data will be used in various reporting tools and dashboards and by whom. There needs to be a clear understanding of what information will be provided to the public and what will be for internal use only. We have over 10 years on experience with GPS/AVL in winter operations so we have many other best practices that we could share.
Maryland DOT - SHA	Make sure the vendor you choose can fulfill all needs and expand data capture for everything you want to use. The vendor should have enough technical experience to ensure the activities you desire to be measured are done so on a meaningful way.

Agency	General Lessons Learned
Massachusetts DOT	The investment in GPS/AVL will provide sufficient operational data to inform maintenance activities and ensure that timelines (such as roadway treatment) are being met.
Michigan DOT	We are almost exclusively using AVL with just winter operations. we do have a few herbicide trucks that also use AVL
Minnesota DOT	Start with a system that fits the agency needs and look to the future development needs, be sure the system/vendor is capable of providing a system upgrade as the technology grows. Consider one contract for MDSS/AVL if that is the direction you plan to go. One vendor as a prime and the other as a sub-contractor, this is important for good cooperation with the two vendors. Cost of implementation is always a concern but needs to be weighed against the potential benefits of the current deployment and future needs/wants. The ability to monitor the overall fleet has led to a reduction in idle time, driver safety habits, material application during snow and ice as well as being able to follow up with the public on tort claims and vehicle locations on complaint that come up.
Missouri DOT	Communication, Communication & Communication! Field operators will feel this is "big brother" watching every move they make and another mechanism to "catch them" doing something wrong. MoDOT is not using the information for disciplinary measures, however, we are having supervisors have coaching moments with individuals when an at-risk behavior shows up on a report. Put a clear communication message together on what the system is and how the system will be used and the benefits to not only the department but the benefit to the operators of our vehicles. Work closely with your AVL/GPS account manager on any customized reports you want produced. Verify the data within those reports to make sure the system is pulling it correctly before sending anything out to field personnel.
Montana DOT	We simply use a limited number of devices for plow cameras that are able to be viewed by the public. We had a very specific use case for the product. having a limited and specific use case made implementation easier.
Nebraska DOT	Nothing continues to work properly without maintenance. A service contract may be needed to ensure the equipment continues to work as intended. Technology advances will render equipment obsolete within 5-10 years, so plan for replacement. Have a good understanding of your goals before specifying equipment and the software that will be used. Cellular coverage has improved and is more reliable than it was a few years ago. Shared data plans can save money.
New Hampshire DOT	Start with collecting small amount of data and plan to increase the amount different data you collect over time or you will be slammed with too much data to try to deal with.
Norwegian Public Roads Administration	Data storage, data analyses and data visualization is a difficult task. But it is crucial to have good aggregated data to utilize the data for different purposes (i.e. following-up the contract, quality indicators, etc.). Be aware of the GDPR (Genera Data Protection Regulation).
Ohio DOT	Make sure you have complete, 100% buy in from all points.

Agency	General Lessons Learned
Oregon DOT	As stated previously Oregon Department of Transportation has a fledgling effort. We have had various staff moving this direction but are only beginning to look at AVL/GPS comprehensively and in a more integrated uniform fashion. We look forward to continuing to share with and learn from others.
Pennsylvania DOT	Shop around and find what works best for you. Some systems have a lot that can be added to it and others do not.
Regional Municipality of Niagara, Canada	Know the implementation and annual operational costs including who owns the hardware with lifecycle costs or lease as part of monthly costs, system features (over speeds, idle time, diagnostics, integration with fleet management software, reporting capabilities, administration effort, method of showing and reporting where units have been - i.e. breadcrumb trail) needed for agency, policies to support using for discipline or public use,
Rhode Island DOT	It is very helpful for monitoring performance for non-winter operations, specifically sweeping and mowing. It is also helpful in the claims process to verify whether or not our winter vehicles were even in the areas of claimed damage.
Road Commission for Oakland County, MI	Make sure you have a well thought out plan for the system and possibly demo it before purchasing the entire program. IE: The AVL system at my agency has the capability of tracking material use but for some reason we have had a hard time getting that data out. The type of spreaders we have, the setting etc. are an issue. Why pay for a feature that does not work. We are continuing to work on it but maybe that would be a function that could be added on later.
Tennessee DOT	Well worth it in winter activities, and likely worth it in other activities, we're just not quite there yet.
Texas DOT	Make sure your AVL/GPS provider has sufficient coverage area to ensure that assets are reporting accurately. Make sure you have internal policy and procedures in place to support your AVL/GPS program. Make sure you have internal processes in place to address or troubleshoot modems that go "dark". Ensure that AVL/GPS provider has sufficient logistical and supply chain support for providing new/additional/replacement modems and wiring harnesses. Use vehicle OEM modems when and where possible.
Town of Lexington, MA	We are concentrating on Operations Optimization
Utah DOT	Make sure the provider can connect with controllers and equipment sensors to pass data. Make sure you have cellular coverage, or that the modem is compatible with the local networks. Ensure that the AVL/GPS equipment will not interfere with the vehicle software. Ensue the data can be collected and used based on the Agency needs and not the provider terms. Prepare for a possible long-term commitment, outfitting a fleet with all new equipment from a new AVL/GPS provider could be cost prohibitive. Receive buy in from all users.
Village of Algonquin, IL	Always know where your vehicle/equipment are, excessive speed and idle time; Helps keep the guys honest and can be defended when residents call in
Virginia DOT	It is a great tool for supporting/planning operations and verifying performance.
Wisconsin DOT	Training is the key. Many users don't even know how to use the software.

Question 2. May we contact you with follow-up questions about your system(s)?

Yes	No	No response
39	4	2

3.3 Summary of Vendor Survey Responses

The survey for AVL/GPS vendors consisted of 15 questions organized into the following 3 parts:

- Part A – Questions on the types of clients for which AVL/GPS systems have been installed.
- Part B – Questions on how AVL/GPS system can be transferred from vehicles to other vehicles within an agency fleet.
- Part C – Questions on deployment experience that the vendors would like to share and whether follow-up questions on the AVL/GPS system could be requested.

The survey was provided to sixteen companies in the AVL/GPS industry, though only four vendors responded to the survey. AVL/GPS manufacturers and vendors invited to participate in the survey are listed below. Manufacturers and vendors that responded to the survey are marked in bold.

- Ameritrak
- Certified Power Solutions
- ***Delcan Technologies***
- Delmarva Communications
- ***Fleetistics***
- Gauge
- Geotab
- Linxup
- Location Technologies
- One Compass
- Raven Industries
- ***Skyhawk Telematics***
- Tallysman
- Trimble
- Verizon Connect
- ***Zonar Systems***

3.3.1 Part A: Basic Information

The first part of the survey contained four questions to help understand the types of clients for which AVL/GPS systems have been installed by various vendors.

Question 1. Please indicate the types of clients of your GPS/AVL systems? (Select all that apply)

Type of Clients	Vendors Reported
Highway agencies for snow and ice removal	4
Highway agencies for roadway construction activities	0
Public safety agencies	1
Freight companies for fleet management	2
Utility companies	2
Airports (for runway/taxiway maintenance)	0

Type of Clients	Vendors Reported
Agriculture/farming industry	2
Other (please specify)	2
People Transportation (public and private)	1
Service companies - pest control, HVAC, plumbing, security etc.	1

Question 2. Do you recommend specific GPS/AVL systems based on the client's operations (for example: one system for transportation winter maintenance vs. another system for farming operations)?

Yes	No
1	3

Question 3. Approximately how many transportation agencies (state and municipal transportation and public works departments) have installed GPS/AVL systems from your company?

Vendor	Response
Zonar Systems	100's
Skyhawk Telematics	23 US, 13 Ca. 3DOT's
Parsons Corp.	No response
Fleetistics	Uncertain

Question 4. Approximately how many clients other than state DOTs and public works departments have installed GPS/AVL systems from your company?

Vendor	Response
Zonar Systems	1000's
Skyhawk Telematics	Mostly government, Have the two largest utilities in Ca. totaling 15,000 units
Parsons Corp.	No response
Fleetistics	Uncertain

3.3.2 Part B: Equipment Transferability

The second part of the survey contained nine questions to help understand the level of equipment transferability with AVL/GPS system equipment.

Question 1. Does your company have clients that move GPS/AVL units from a truck/equipment to another for multiple uses or during different time of the year?

Yes	No	No response
2	0	1

Question 2. If you answered "Yes" to the previous question, please indicate the type(s) of clients.

Types of AVL/GPS Clients	Vendors Reporting
Transportation agencies, such as state DOTs or city/county public works departments	0
Agricultural agencies / farm owners	0
Construction	0
Airport Authorities	0
Other (please specify)	2
Truck Leasing Companies	1
City government	1

Question 3. Does your company have any transportation or public works agency clients that move GPS/AVL units from winter maintenance vehicles (i.e. snowplows) to non-winter maintenance vehicles/equipment (such as mowers and paint trucks)?

Yes	No	No response
0	3	1

Question 4. Does your company have clients other than state DOTs and public works departments that move GPS/AVL units from a vehicle/equipment to another for multiple uses or during different seasons?

Yes	No	No response
1	2	1

If yes, can you provide the client names and contact information (email and/or phone numbers)?

Vendor	Response
Zonar Systems	Penske Truck Leasing
Fleetistics	I selected no as I am not certain, we may have clients doing it that we are not aware of

Question 5. Does your company recommend to clients that they can move GPS/AVL units to different trucks or equipment for multiple uses or during different seasons?

Yes	No	No response
2	1	1

Question 6. Does your company offer equipment support to clients for multi-season uses of GPS/AVL units in multiple different types of vehicles?

Yes	No	No response
1	2	1

Question 7. Have clients requested equipment support from your company to support transferring GPS/AVL units to different types of vehicles for multiple uses?

Yes	No	No response
0	3	1

Question 8. Has your company deployed or considered the deployment of connected vehicle technology as part of your GPS/AVL system?

Yes	No	No response
1	2	1

Question 9. Has your company deployed or considered the deployment of connected vehicle technology as part of your GPS/AVL system?

Yes, currently deployed	Yes, considered	No	No response
2	1	0	1

3.3.3 Part C: Deployment Experience

The final part of the survey contained the following two questions to gather lessons learned that the agencies would like to share in the survey and determine whether or not follow-up questions on the AVL/GPS system could be requested.

Question 1. What practical advice can be offered to transportation agency clients that are interested in implementing GPS/AVL technologies for both winter and non-winter maintenance operations?

Agency	General Lessons Learned
Zonar Systems	To make the transition as easy as possible, I would advise those agencies to install the wiring component of the GPS in all applicable vehicles as well as any ancillary equipment support (tablet docks, vehicle inputs, etc.). I would also advise them to make the install location of the GPS safe but easily accessible. This will ensure that the transition process is easy any time they are required to do it.

Agency	General Lessons Learned
Skyhawk Telematics	1) Make the AVL company PROVE they can do what they say they can do. 2) Compare the material amounts showing on the report to the material amounts showing on the salt controller. (DOT's are just starting to look at the material totals) 3) Cost of the hardware has come down so much that municipalities can put modems on standby during off season cheaper than having mechanic move the modem and test.
Fleetistics	Have vehicles set up with Y cables or T harnesses so only the device needs to be moved

Question 2. May we contact you with follow-up questions about your system(s)?

Yes	No	No response
3	0	1

3.4 Review of Survey Responses and Agency Categories

Based on survey responses, agencies were grouped into the following categories for further review, as shown previously in Table 1:

- Agencies using AVL/GPS equipment for winter maintenance only
- Agencies using AVL/GPS equipment for both winter and non-winter maintenance
- Agencies using AVL/GPS equipment for non-winter maintenance only

Given that the purpose of the study was to perform case studies on agencies that use AVL/GPS system for non-winter or year-round maintenance purposes, the agencies that indicated they only use AVL/GPS systems for winter maintenance purposes were not considered for a case study review. This resulted in 12 of the 45 agencies with AVL/GPS systems were removed from further analysis.

Among the remaining 33 agencies, two agencies indicated they used AVL/GPS systems only for non-winter maintenance purposes. Given the desire stated in the project scope to consider developing a case study on at least one agency that is either not within the Clear Roads consortium or that does not conduct winter maintenance activities, these two agencies were analyzed separately, as discussed later in Section 3.6.

3.5 Winter and Non-Winter Maintenance Agency Analysis

Given the high number of agencies that use AVL/GPS systems for both winter and non-winter maintenance, a numerical scoring method was designed to assess and rank each agency's level of AVL/GPS implementation for year-round maintenance activities. This method was applied to responses received to several survey questions as shown in Table 3.

Table 3. Criteria for Evaluating Case Study Agencies (Winter and Non-Winter Maintenance)

Evaluation Criteria	Survey Questions	Value	Weighted Value
Agency transfers AVL/GPS equipment between winter and non-winter maintenance vehicles (Yes/No)	A.4	1 for Yes; 0 for No	5
Agency integrates AVL/GPS system with other systems or equipment for non-winter maintenance operations (Yes/No)	B.1	1 for Yes; 0 for No	2
Types of data collected by agencies in non-winter maintenance activities	B.2	Number of types of Data	2
Level of data usage collected by AVL/GPS systems	B.6	Number of uses of data collected	2
Has your agency measured the time and cost associated with AVL/GPS equipment transfer activities?	C.5	1 for Yes; 0 for No	2
Has your agency measured quantifiable benefits of implementing AVL/GPS for year-round maintenance uses?	C.6	1 for Yes; 0 for No	2
Size of non-winter maintenance fleet	A.3a	Size of Fleet (Scale of 0 to 6)	2
Types of non-winter maintenance activities that use AVL/GPS equipment	A.3b	Number of Activities	1
Agency has developed mechanical configurations to guide the equipment transfer activity	C.4	1 for Yes; 0 for No	1

The research team utilized a scoring method to assess and rank each agency's level of use of AVL/GPS systems for winter and non-winter maintenance activities. The values that can be determined from the survey responses were multiplied by a weighted value that is assigned based on the importance of that criterion, with a higher weight indicating a greater importance of the criterion. Each survey response value is multiplied by the assigned weighted value, and these weighted values are added together for each agency. The highest weighted sum totals can indicate which agencies would be good candidates for case study interviews, as shown in Table 4.

Table 4. Summary of Agency Scoring and Ranking (Winter and Non-Winter Maintenance)

Evaluation Criteria/Survey Questions*	A.4	B.1	B.2	B.6	C.5	C.6	A.3a	A.3b	C.4	Weighted Sum
Weighted Value	**5**	**2**	**2**	**2**	**2**	**2**	**2**	**1**	**1**	
Agencies										
Missouri DOT	1	1	5	7	0	1	4	4	0	**45**
City of West Des Moines, IA	0	1	2	6	0	0	2	7	0	**29**
City of Farmington Hills, MI	0	1	2	4	0	1	2	7	1	**28**
Illinois DOT	0	1	4	4	0	0	2	5	0	**27**

Evaluation Criteria/Survey Questions*	A.4	B.1	B.2	B.6	C.5	C.6	A.3a	A.3b	C.4	Weighted
Weighted Value	5	2	2	2	2	2	2	1	1	Sum
Agencies										
Colorado DOT	0	1	1	5	0	0	2	8	0	**26**
Pennsylvania DOT	0	0	2	5	0	0	3	6	0	**26**
Texas DOT	0	0	1	3	0	1	5	6	0	**26**
City of St. John's (Canada)	0	1	2	3	0	0	3	7	0	**25**
Minnesota DOT	0	1	1	6	0	1	2	3	0	**25**
Rhode Island DOT	0	1	2	4	0	0	2	7	0	**25**
City of Oslo	0	0	3	5	0	1	1	3	0	**23**
New Hampshire DOT	1	1	2	3	0	0	1	3	0	**22**
Massachusetts DOT	1	0	2	4	0	0	1	2	0	**21**
Town of Lexington, MA	0	0	2	3	0	1	2	5	0	**21**
Maryland DOT-SHA	0	0	2	3	0	0	3	4	0	**20**
Utah DOT	0	0	1	5	0	0	2	4	0	**20**
Virginia DOT	0		1	5	0	0	3	2	0	**20**
Washington State DOT	0	1	3	3	0	0	1	4	0	**20**
Delaware DOT	0	0	1	3	0	0	3	5	0	**19**
East End Crossing Partners	0	1	3	3	0	0	1	3	0	**19**
Village of Algonquin, IL	0	0	2	3	0	1	1	4	0	**18**
Idaho Transportation Department	0	0	2	3	0	0	2	3	0	**17**
Michigan DOT	0	1	3	4	0	0	0	1	0	**17**
Oregon DOT	0	1	3	2	0	0	1	3	0	**17**
City of Iowa City, IA	0		1	2	0	0	2	5	0	**15**
Iowa DOT	0	0	2	3	0	0	1	2	0	**14**
Regional Municipality of Niagara, Canada	0	0	2	1	0	0	2	4	0	**14**
City of Bozeman, MT	0	0	1	3	0	0	1	3	0	**13**
City of Dublin, OH	0	1	1	2	0	0	0	0	0	**8**
Norwegian Public Roads Administration	0	0	1	1	0	0	0	1	0	**5**
Arizona DOT	0	0	0	0	0	0	0	2	0	**2**

***Survey Questions/Evaluation Criteria:**

A.4: Transfers AVL/GPS equipment to non-winter maintenance vehicles
B.1: Integrates AVL/GPS system with other systems or equipment for non-winter maintenance operations
B.2: Types of data collected in non-winter maintenance activities
B.6: Uses of data collected by AVL/GPS systems
C.5: Measures the time and costs associated with AVL/GPS equipment transfer
C.6: Has quantifiable benefits of implementing AVL/GPS for year-round maintenance
A.3a: Size of non-winter maintenance fleet
A.3b: Types of non-winter maintenance vehicles/equipment with AVL/GPS
C.4: Has mechanical configurations to guide AVL/GPS equipment transfer

Based on this ranking exercise, agencies with highest scores were recommended for a case study. It was recommended that the **Missouri DOT, City of West Des Moines, IA, City of Farmington Hills, MI, and the Illinois DOT** be selected for case study Interviews. This was based on their high usage of AVL/GPS

equipment for non-winter maintenance activities and the multiple uses of the AVL/GPS system to support their operations. The recommended agencies and their characteristics are summarized in Table 5.

Table 5. Characteristics of Recommended Case Study Agencies (Winter and Non-Winter Maintenance)

Characteristics	Missouri DOT	City of West Des Moines, IA	City of Farmington Hills, MI	Illinois DOT
Types of non-winter maintenance activities and size of fleet				
Mowers	21-50	< 20	< 20	0
Paint trucks	21-50	< 20	0	< 20
Street Sweepers	< 20	< 20	< 20	0
Jetter Trucks	0	< 20	< 20	0
Light-weight vehicles	301-500	21-50	21-50	101-300
Tanker trucks (for non-winter maintenance)	21-50	< 20	< 20	< 20
Pesticide sprayer vehicles	21-50	0	< 20	0
Temporary work zones / roadway maintenance equipment and vehicles	51- 100	< 20	21- 50	101- 300
Other	21- 50 (Tractors, skid steers, loaders, backhoes, aerial units, drills)			> 500 (Plow trucks for non-winter maintenance)
Types of data collected by agencies in non-winter maintenance activities				
Location information with lat-long coordinates	Yes	Yes	Yes	Yes
Task-based information	Yes	Yes	Yes	Yes
Material application data	Yes	No	No	No
Dash-cam video	Yes	No	No	Yes
Other	All at-risk driving behavior			Engine run hours
Level of data usage collected by AVL/GPS systems				
Maintenance operations planning	Yes	Yes	Yes	Yes
Monitor and improve shop or field activities	Yes	Yes	Yes	Yes
Process automation	Yes	Yes	No	No
Paperwork reduction	Yes	Yes	No	No
Environmental documentation (such as MS4 paperwork for street sweeping)	No	Yes	Yes	No
Public information (i.e. inform the public regarding the locations of maintenance activities)	Yes	Yes	No	Yes

Characteristics	Missouri DOT	City of West Des Moines, IA	City of Farmington Hills, MI	Illinois DOT
Tort claims	Yes	Yes	No	Yes
Other	Proactive Driver Safety Program; Key metrics, such as speeding and seat belt use;		Safety, checking on mowing crews and seasonal	
Transfers AVL/GPS equipment between winter and non-winter maintenance vehicles	Yes	No	No	No
Integrates AVL/GPS system with other systems/equipment for non-winter maintenance operations	Yes	Yes	Yes	Yes
Has mechanical configuration guide for equipment transfer	No	No	Yes	No
Measured time and cost associated with AVL/GPS equipment transfer	No	No	No	No
Measured quantifiable benefits of AVL/GPS for year-round maintenance uses	Yes	No	Yes	No

3.6 Non-Winter Maintenance Agency Analysis

As noted previously, two agencies indicated they used AVL/GPS systems exclusively for non-winter maintenance purposes. Given the desire stated in the project scope to consider developing a case study on at least one agency that is either not within the Clear Roads consortium or that does not conduct winter maintenance activities, these two agencies are analyzed separate from the other remaining agencies that use AVL/GPS system for both winter and non-winter maintenance.

These two agencies and highlights of their survey responses are presented in Table 6. Based on the responses provided, it is recommended that the **Alabama DOT** be selected for a case study interview given their high usage of AVL/GPS equipment for non-winter maintenance activities.

Table 6. Characteristics of Candidate Case Study Agencies (Non-Winter Maintenance Only)

Agency	Alabama DOT	Prince William County Service Authority
Types of non-winter maintenance activities and size of fleet		
Mowers	101 - 300	0
Paint trucks	< 20	0
Street Sweepers	< 20	0
Jetter Trucks	0	< 20
Light-weight vehicles	301 - 500	< 20
Tanker trucks (for non-winter maintenance)	21- 50	< 20

Agency	Alabama DOT	Prince William County Service Authority
Pesticide sprayer vehicles	< 20	0
Temporary work zones / roadway maintenance equipment and vehicles	101 -300	< 20
Types of data collected by agencies in non-winter maintenance activities		
Location information with lat-long coordinates	Yes	Yes
Task-based information	No	No
Material application data	Yes	No
Dash-cam video	No	No
Other (please specify)		
Level of data usage collected by AVL/GPS systems		
Maintenance operations planning	No	Yes
Monitor and improve shop or field activities	Yes	Yes
Process automation	No	No
Paperwork reduction	No	No
Environmental documentation (such as MS4 paperwork for street sweeping)	Yes	No
Public information (i.e. inform the public regarding the locations of maintenance activities)	No	No
Tort claims	Yes	Yes
Other (please specify)	Quality Control	No
Integrates AVL/GPS system with other systems/equipment for non-winter maintenance operations? (Yes/No)	Yes	Yes
Measured quantifiable benefits of implementing AVL/GPS for year-round maintenance uses? (Yes/No)	No	No

3.7 Recommendations on Case Study Agencies

Based on the survey responses gathered and reviewed, the research team offers the following recommendations for the selection of case study agencies:

- Four transportation agencies for case studies that use AVL/GPS systems for both winter and non-winter maintenance operations. This includes two city-level agencies that are not currently members of the Clear Roads consortium
- One transportation agency for a case study that uses AVL/GPS systems for non-winter maintenance only, which is also not currently a member of the Clear Roads consortium

Agencies recommended for case studies are listed in Table 7.

Table 7. Recommended Case Study Agencies

Categories	Case Study Agencies
Transportation Agencies with AVL/GPS for Both Winter and Non-Winter Maintenance	• Missouri DOT • City of West Des Moines, IA • City of Farmington Hills, MI • Illinois DOT
Transportation Agencies with AVL/GPS for Non-Winter Maintenance Only	• Alabama DOT

4. Case Study Summary

Upon selection of the agencies for detailed case studies, the research team contacted key representatives from each agency to schedule virtual interviews and provided an overview of the subjects which would be discussed with each agency.

4.1 Introduction

To obtain the information needed for developing case study reports, virtual interviews were conducted with multiple levels of agency staff. Table 8 presents the interview dates with each agency and agency representatives participated in the interviews.

Table 8. Interviews for Case Studies

Agencies	Interview Dates	Representatives
Missouri DOT	Feb. 7 & 14, 2022	Paul Denkler, Natalie Roark
City of West Des Moines, IA	Jan. 26, 2022	Bret Hodne, Jeff Sherman, Rian Rasmussen
City of Farmington Hills, MI	Jan. 28, 2022	Bryan Pickworth, Kevin McCarthy
Illinois DOT	Jan. 19, 2022	Amy Eller, Laura Shanley, Randy Neal
Alabama DOT	Jan. 20, 2022	Andrew Harry, William Butler, Jacob Hodnett, Howard Peavey, Phillip Day, Zach Bennett

A set of interview questions were prepared and shared with case study agencies prior to the interviews. The interviews covered questions in the following categories:

- General overview of the agency's AVL/GPS system and operational goals
- System hardware, types of vehicles/equipment with AVL/GPS and integration of onboard technology
- Data collection, management and utilization
- System installation, operations, maintenance and training
- Lessons learned

The focus of the interviews was designed to gather sufficient information for the case study reports. A summary of the information gathered from each of the virtual interviews is contained in the Appendices B through F of this report.

A total of five case study reports were developed. They are available on the Clear Roads website (http://clearroads.org/). A high-level summary of the case study results and findings are presented on the following pages.

4.2 Case Study 1: Missouri DOT

4.2.1 Agency Overview and AVL/GPS Project Background

The Missouri DOT (MoDOT) is divided into seven districts as shown in Figure 1. Each MoDOT district contains a maintenance superintendent and a maintenance supervisor responsible for winter and non-winter maintenance operations. The St. Louis, Central, and Southwest districts perform many pilot projects with the AVL/GPS system used in the state to determine effectiveness for use with other districts of the state.

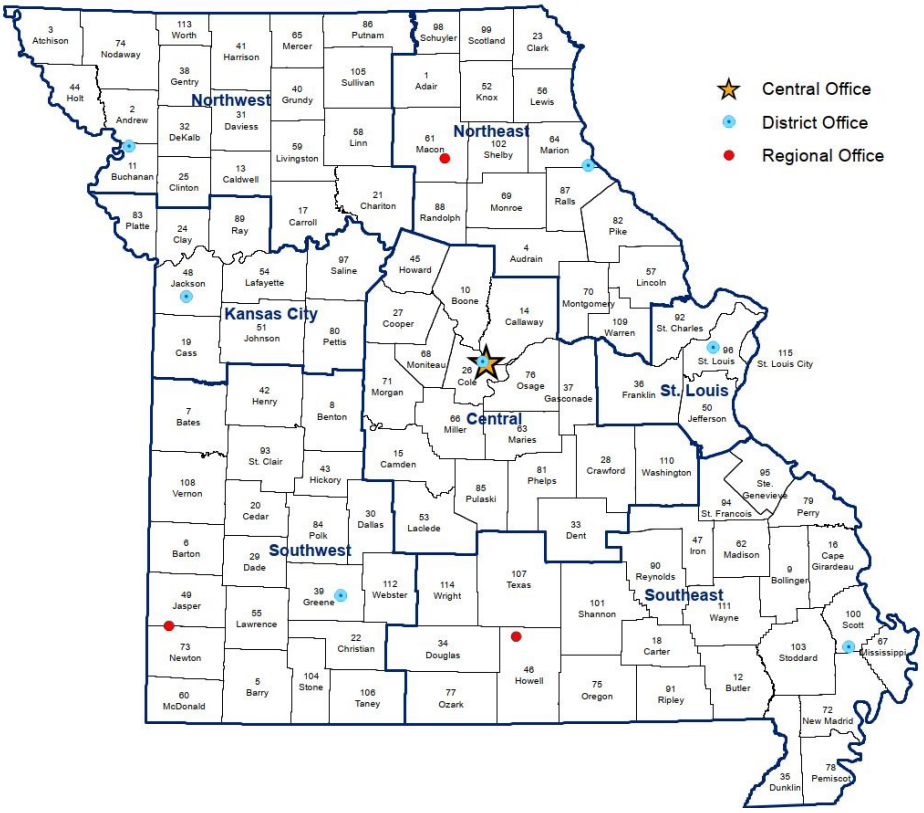


Figure 1. MoDOT Districts
Source: MoDOT

Three MoDOT districts (Southwest, Central, and St. Louis) initially began with a pilot of the AVL/GPS system from Geotab in 2015. The districts initially wanted to test an AVL/GPS system for engine diagnostics features to determine when check engine lights were activated and measure vehicle mileage among other items. Each of the 3 districts individually managed its procurement through a solicitation process for the

AVL/GPS technology, and each district selected Geotab as its AVL/GPS vendor. While the system was initially installed for its engine diagnostics capabilities, improvement in driving safety became a driving factor later for statewide implementation.

Over time, each of the three districts added different features of the system to their maintenance operations, which made it difficult to evenly compare how the different Geotab systems were being used. There were also different "silos" in which AVL/GPS information was stored for each district, which also made it difficult to evaluate the benefits of using the system in those districts.

4.2.2 MoDOT System Procurement

In 2018, MoDOT established an AVL/GPS team to consolidate data from these different silos into a central source of data and to begin planning for an expansion of the system statewide. As a first step, MoDOT utilized Sourcewell as a procurement process to select one equipment distributor for all three MoDOT districts involved in the initial pilot. This also allowed for MoDOT to consolidate the data and information from the districts into a central location for better understanding how the system was used in all three districts. This in-house central data source for MoDOT is referred to as the Maintenance Management System (MMS).

As a second step in the procurement for a statewide expansion, MoDOT coordinated with the California Department of Transportation (Caltrans) to review a procurement specification that was eventually used by Caltrans to select their AVL/GPS system vendor. Caltrans developed the specifications and was open for other state DOTs to use, and MoDOT adopted the specifications for use in its AVL/GPS system procurement statewide. In addition, cities and counties within Missouri can also use the MoDOT contract to purchase Geotab devices for their public works fleets if desired. MoDOT works with a single equipment distributor for its equipment as well.

4.2.3 MoDOT System Implementation and Integration

By early 2022, MoDOT has installed the Geotab AVL/GPS system on 92% of their 1,500 heavy-duty vehicle fleet that are used as snow plows in winter periods and for other uses in non-winter periods. Meanwhile, 46% and 45% of the medium-duty and light-duty (passenger) vehicles, respectively, were equipped with the Geotab AVL/GPS system. The system includes a GO9 vehicle hardware and a web-based user interface.

MoDOT utilizes their AVL/GPS system to support multiple types of non-winter maintenance operations, including:

- Roadside mowing. This involves the use of a "protector" heavy-duty vehicle that follows on the roadway shoulder behind the mower. The protector vehicle has AVL equipment installed, and MoDOT plans to install AVL on mowers in the future.
- Roadway paving. Heavy duty trucks with AVL equipment can be monitored for when they arrive at a quarry. Driver identity can also be monitored through the AVL system.
- Seal coat operations are performed every other year. AVL system in the vehicles is used by supervisors to direct vehicles operators on the route they should follow when they finish seal coating a segment of roadway.

- Paint striper vehicles. The system is currently measuring only when paint sprayers are on or off, though MoDOT plans to gather additional information from vehicles on types and amount of paint applied by vehicles in a future pilot project.

The GO9 vehicle hardware device used with MoDOT is displayed in Figure 2. The device plugs into the OBD-II port on the vehicles which is located in many vehicles in area near the brake and speed pedals out of sight of the vehicle driver. The device receives power from the vehicle and includes cellular technology to communicate data from the vehicle back to the central software. Vehicle diagnostic data is gathered primarily from use of the GO9 device connecting to the OBD-II port. In addition to the GO9 device, MoDOT has installed a vehicle "T"-harness that connects other on-board vehicle systems on heavy-duty vehicles with the OBD port for integration with the GO9 system. The harness allows for additional data on vehicle operations to be transmitted, such as street sweeper broom "up/down" status.

Figure 2. Geotab GO9 Vehicle Hardware (Front and Back) for Vehicles with OBD-II Port

All Geotab GO9 devices communicate data from vehicles using a cellular modem that is built into the Geotab hardware, and no additional cellular antennae are required on the vehicles to communicate data from the vehicles. Geotab allows for client agencies to select a preferred cellular provider that has the greatest amount of cellular coverage within its service area.

If installed near and directly accessible to the operator, the Geotab unit in the vehicle has a tendency to be accidentally knocked out of place by vehicle operators, which would impact data reporting. In rare cases, the Geotab unit may be intentionally removed from the vehicle. A Watchdog report in the central software can be used to detect missing units or vehicles in the system for finding these vehicles and operators. To alleviate the issue, MoDOT staff installed the devices behind the vehicle dash with a harness where the device was effectively out of sight of the operator.

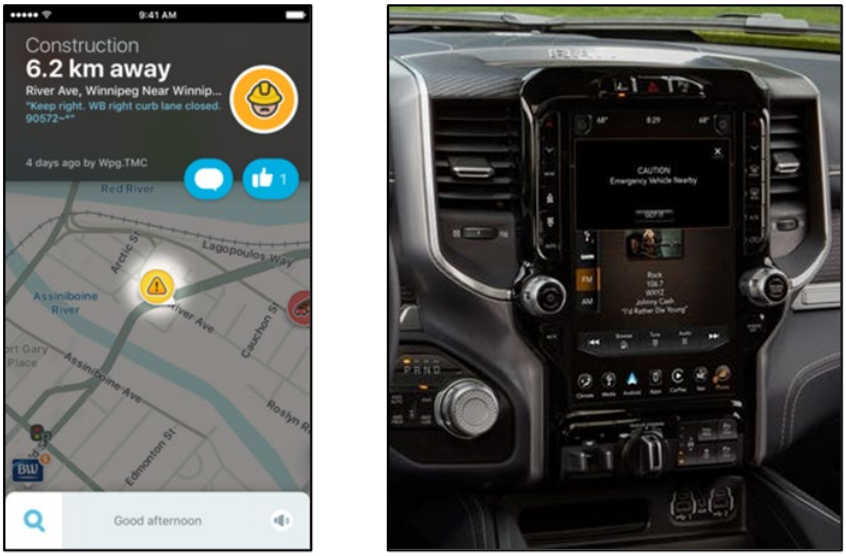
4.2.4 MoDOT System Software

MoDOT utilizes the web-based Geotab central software for viewing vehicle locations and for generating automated reports. MoDOT district supervisors utilize the Geotab central software for viewing vehicle locations in real-time within their respective district during inclement weather events. MoDOT central office staff can view vehicle locations statewide for weather events that cross multiple districts. MoDOT staff also utilize the Geotab software to develop custom reports that can highlight safe driving behavior in each district.

MoDOT is currently testing a pilot project with 500 vehicles in which overhead warning lights activated on the vehicle can trigger an in-vehicle message to passenger vehicles approaching along the roadway. The vehicles include Truck Mounted Attenuators (TMAs), emergency response trucks, and snow plow vehicles. The overhead warning lights on these types of vehicles are connected to an auxiliary port on the Geotab harness. When the overhead lights are activated, Geotab hardware can communicate the activation to the Geotab central software. Geotab has developed an integration of their central software with a separate system developed by HAAS Alert that is known as Safety Cloud.[1]

BlueArrow Telematics provides a Safety Cloud service activation to MoDOT through an integration with the Geotab system. Safety Cloud has, in turn, integrated their system with two different companies – Waze and Stellantis – which can relay the warning messages to passenger vehicles that are approaching MoDOT vehicles with their lights activated. The Safety Cloud integration with Waze allows any passenger vehicles actively using the Waze app for in-vehicle navigation to receive a message through Waze about a construction type of vehicle that they are approaching. This would be any MoDOT vehicle that has their overhead lights activated.

The Safety Cloud integration with Stellantis allows for messages to be sent directly to the in-vehicle navigation system on vehicles that have been manufactured since 2018 by Chrysler, Jeep, Dodge, and Ram. Stellantis recently activated this capability in 2021 on those types of vehicles through its partnership with HAAS Alert and its Safety Cloud system. Figure 3 illustrates of the different types of in-vehicle alerts that can be provided.



Waze Alert in Mobile App **In-vehicle Navigation System Alert**

Figure 3. HAAS Alert Messaging through Waze Mobile App and In-vehicle Systems
Source: https://www.imore.com/waze-everything-you-need-know; https://www.freep.com/story/money/cars/chrysler/2021/11/06/jeep-ram-chrysler-dodge-safety-alerts-test/6273843001/

[1] Source: https://www.haasalert.com/integrations.

4.2.5 MoDOT Data Collection and Management

The data collected by MoDOT on non-winter maintenance operations is summarized in Table 9.

Table 9. Types of Non-Winter Maintenance Operations AVL/GPS Data Collected

AVL/GPS Data	Type of Non-Winter Maintenance Operations
Miles of Roadway Paved	Roadway paving
Vehicle Location Data	Seal coat operations
Width of spraying Total acreage of herbicide treatment	Herbicide Spray Operations
Miles of sweeping operations completed	Street Sweeping
Seat belt usage	Safety Dashboard
Vehicle speeds over thresholds	Safety Dashboard
G-Force Measures over threshold	Safety Dashboard
Engine diagnostics	Vehicle Maintenance Operations
Striping On/Off Amount of paint and striping types (future)	Paint striping
Acres of mowing completed (future)	Roadside mowing

MoDOT has developed an in-house Maintenance and Management System (MMS) which receives data from Geotab on performance measures such as miles of roadway that have been treated in winter weather and the number of hours that operators have logged during maintenance operations. An Application Programming Interface (API) has been developed by Geotab to allow for data gathered through the AVL system to be made available to the MMS, which retrieves the data for storage in the MMS.

4.2.6 MoDOT System Data Usage

In addition to location tracking, MoDOT utilizes data from the AVL/GPS system for engine diagnostics and for the creation of a dashboard report that presents a Safety Scorecard that can highlight safe driving behaviors by each district in the state. MoDOT's use of the system data is described below.

Safe Driving Behavior Reporting

MoDOT's primary intent for using the AVL/GPS system has been to develop a Proactive Driver Safety Program. By observing key metrics, such as speeding and seat belt use, MoDOT desires to minimize the potential for injury and keep maintenance and liability costs low. The proactive nature of the program is also intended to prevent accidents and injuries before they occur, which benefits both our MoDOT employees and the general public.

MoDOT has worked with Geotab to develop a Safety Dashboard report to encourage safe driving by each district. The dashboard can provide an overall safety score that is based on metrics such as speeding, harsh braking, backing up, seatbelt use, and other items. This safety report can be generated at different intervals (weekly, monthly, 3 months, 6 months) to allow for viewing of trends in overall safety behaviors

by the operators. The safety dashboard can also help to reduce vehicle maintenance cost by reducing the wear and tear on fleet vehicles over time.

Another safety feature that MoDOT has tested with Geotab is gathering data on G-force measures gathered from a vehicle accelerometer and lateral movements that are detected on the vehicle. This would allow for any emergency messages to be transmitted in case a vehicle overturns or is exhibiting un-safe driving behaviors on roadway curves.

Engine Diagnostics

MoDOT utilizes the AVL system for retrieving engine diagnostics from fleet vehicles and assessing whether or not vehicles are required for immediate services. Geotab hardware can interface with heavy duty vehicles manufactured by Navistar and can receive real-time engine diagnostics through an OnCommand Connection enabled by Navistar. Supervisors that are using Geotab software can receive an alert about the diagnostic issue and quickly respond to the issue, instead of waiting for a separate report on engine diagnostics to be generated by Geotab software on a daily or weekly basis. MoDOT was working on a similar effort to gather engine diagnostic information from light duty vehicles. It was noted that other manufacturers of heavy duty vehicles do not provide the same type of linkage, so this is unique to only Navistar brand vehicles.

MoDOT is currently testing out a process through Geotab referred to as ScanAlert, which would single out serious engine diagnostic alerts and then send an automated email directly to supervisors about the issue. This allows for timely alerts to get to supervisors who may not be actively viewing the Geotab software when the alert is detected. Initially, several emails about the same alert were sent to supervisors repeatedly, but MoDOT was able to determine the problem and reduce the amount of emails being sent about the same problem.

4.2.7 MoDOT System Benefits and Costs

MoDOT staff noted that the statewide contract that allowed for expansion to all districts came with a per-vehicle cost of $18.50 per vehicle per month for use of the Geotab GO9 system. This was a significant reduction from the previous price MoDOT was paying through the Sourcewell contract and the independent district contracts that were initially set up in 2015.

MoDOT staff noted that the initial installation process of the GO9 Geotab equipment in the vehicle required more time and resources than many of the districts had available at the time. This was due to initially having to locate all of the vehicles and schedule them for the installation. MoDOT staff noted that the overall process takes about 30 to 45 minutes per vehicle for the vehicle harness and the Geotab hardware.

In 2022, MoDOT was planning to review how the use of the Geotab system has impacted the amount of incidents involving MoDOT vehicles and the financial benefits in terms of reduced claims paid as a result of the incidents. This would help to further validate the system benefits to the agency. The system may also be expanded to fleet vehicles used by the Missouri Department of Conservation.

4.2.8 MoDOT Issues and Challenges

Institutional Issues

MoDOT developed a policy to describe how the AVL/GPS system was being used to encourage safe driving among vehicle operators and that it could be potentially used in a disciplinary manner if there were a repeated number of un-safe driving violations reported by the system. The policy was provided to vehicle operators and helps to increase their awareness of the system on the vehicles. While maintenance supervisors did not actively monitor specific vehicle locations, they could receive reports on un-safe driving behaviors related to seat belt usage and driving over the speed limit as noted earlier.

It was noted that some vehicle operators were concerned about the system being used in an active disciplinary manner. However, the system has been used to exonerate some drivers from citizen complaints about property damage and has also been used to recover a few stolen vehicles from the fleet in recent years. This has reduced many of the "big brother" types of concerns in many cases.

Technological Issues

After the G-force alerts were first implemented, MoDOT found that calibration of the accelerometer equipment would be needed to reduce excessive alerts being provided to supervisors. It was found that vehicles receiving loads at quarries would shake from side to side after receiving a load at the quarry. This was addressed through placing a geo-fence in the Geotab software around the quarry to prevent alerts while loading at the quarry. In other cases, rough conditions on roadways contributed to excessive alerts. MoDOT then performed additional testing on a closed test track used by the Missouri State Highway Patrol for officer training, where MoDOT collected data as the vehicle was driven around the track to understand the proper speed and lateral thresholds to set for determining alerts. This type of calibration helped improve the confidence of supervisors in reviewing G-force alerts for observing un-safe driving behaviors.

Additional calibration was also needed on vehicles for the seat belt reporting. At times, the lack of a passenger seat belt would be detected if any objects were placed on the passenger seat. Over time, the passenger seat belt detection was turned off. In other cases, the driver seat belt was not detecting accurately, which was addressed through a review of the seat belt sensors on the vehicles.

Implementation Issues

MoDOT staff noted that each of the seven districts is assigned a Geotab system administrator who is responsible for inputting vehicle data and categorizing them as passenger, medium duty, and heavy duty in the system. Inconsistent vehicle assignments made by the districts could reduce the accuracy of the safety scorecards that were created through Geotab. This issue was resolved by developing guidance for system administrators on how to categorize vehicles.

4.2.9 MoDOT Lessons Learned

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

- Communication with field operators and district supervisors regarding the value of the system is critical. Field operators may feel that AVL/GPS systems are a "big brother" watching every move they make and another mechanism to catch them doing something wrong. MoDOT is not using

the information for disciplinary measures, but rather having supervisors have coaching moments with operators when an at-risk behavior shows up on a report. Developing a clear communication message on what the AVL/GPS system is and how the system will be used can help both supervisors and operators increase the safety of maintenance operations, and over time, increase the benefit to the department in terms of tort claims, resource usage, and other areas.

- Work closely with the AVL/GPS account manager on any customized reports that an agency may want to have developed. Verify the data within those reports to make sure the system is pulling it correctly before sending anything out to field personnel.
- Regarding the initial use of safety dashboards and other custom reports, MoDOT noted that it may have at first felt like information overload for maintenance superintendents and supervisors. Central office staff worked to communicate the value of the reports to the field office staff and worked to address any issues in the Geotab system reporting as noted. Other agencies should be prepared to communicate the data provided to supervisors and superintendents as part of any efforts to use the AVL/GPS system for custom reporting.
- MoDOT developed an internal AVL/GPS team to consolidate data from different districts that were separately managing their own AVL/ GPS systems each with their own distributor of the equipment. The consistency that was established through procurement of a single AVL/GPS vendor for all seven MoDOT districts has enabled MoDOT to view system data across all districts and to promote safe driving behaviors through the Safety Scorecard report developed with Geotab.
- Through promoting the safety benefits of the AVL/GPS system with a Safety Dashboard that encourages safe driving by each district, MoDOT staff have seen an 85% increase in seat belt usage and a 70% decrease in speeding events over the first year of usage on a statewide basis.

4.3 Case Study 2: City of West Des Moines Public Works Department

4.3.1 Agency Overview and AVL/GPS Project Background

The City of West Des Moines is located in the central part of Iowa to the west of the state capital Des Moines. An outline of the location and city limits are illustrated in Figure 4.

West Des Moines has been using AVL/GPS systems for the past 15 years and has worked with different vendors during that time. The City's focus was on implementing an AVL/GPS system to its entire maintenance fleet, not just to winter maintenance vehicles. Prior to 2021, the City had installed an AVL/GPS system from Webtech Wireless. Prior to procurement, the City Public Works Department coordinated with the City Fleet Department and the Police Department to explore the possibility of an AVL/GPS system procurement for the entire city fleet. The Public Works Department realized that each department had different needs and it would be more costly to procure a system that could be suitable for all department. As such, the City decided to procure a system that could address the specific needs and requirements of the Public Works Department.

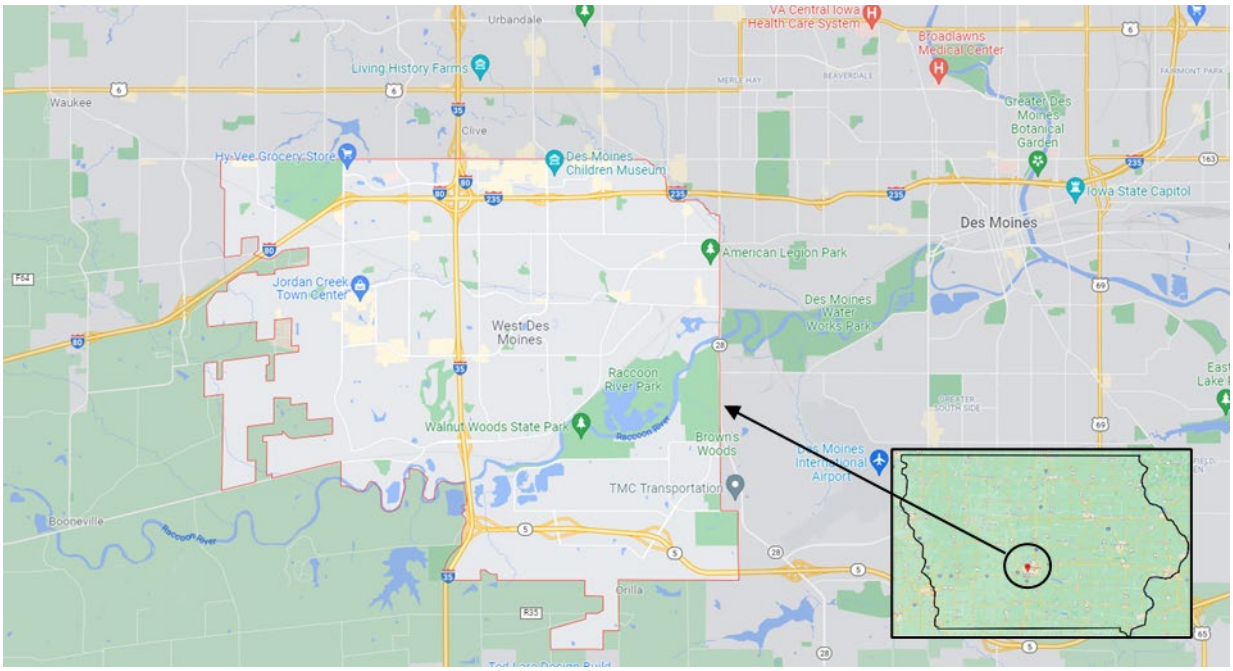


Figure 4. City of West Des Moines
Source: Google Maps

West Des Moines utilized a Polk County procurement package in 2005 for the selection of the Webtech AVL system. An important consideration for the City at that time was the vendor's ability to host the data, the system's reporting capability, and simplicity of the system reports. Over time, the Webtech system began to require a greater amount of repairs and maintenance, and it became less reliable in terms of interfacing with spreader controllers and other equipment on the vehicles.

4.3.2 West Des Moines System Procurement

In 2021, West Des Moines utilized Sourcewell to begin procurement of a new AVL/GPS system. Sourcewell selected Geotab as the AVL/GPS technology vendor through a competitive solicitation process. West Des Moines reviewed the technology solution offered, then procured and installed an AVL/GPS system from Geotab referred to as the "GO9" system for their entire fleet of public works vehicles, which included loaders, graders, sweeper vehicles, paint trucks, light duty trucks, and snow plow vehicles.

West Des Moines has been very pleased with the overall operation of the system since its installation in 2021. While it has been operational for winter maintenance activities, West Des Moines has not had much experience using it for non-winter maintenance activities, though the system would be installed on the entire fleet of public works vehicles for use all year-round.

4.3.3 West Des Moines System Implementation and Integration

West Des Moines' GO9 system included the following equipment:

- GO9 vehicle hardware includes a small device that connects with a vehicle's On-Board Diagnostics (OBD) port for integration with other on-board vehicle systems, such as spreader controller or

plow/broom sensor on the vehicle. The GO9 device also uses cellular technology to communicate data from the vehicles to a web server that is managed by Geotab.

- A vehicle "T"-harness connects other on-board vehicle systems with the OBD port for integration with the GO9 system on City vehicles.
- There are 12 portable Geotab devices that the City provides to independent contractors that clear snow in various areas of the City.
- A web-based user interface is utilized by City staff to view data on vehicle locations in real-time and can also be used to generate different types of reports on maintenance operations.

The GO9 vehicle hardware device is shown in Figure 5. The device receives power from the vehicle and includes cellular technology to communicate data from the vehicle back to the central software. Vehicle diagnostic data is gathered primarily from use of the GO9 device connecting to the OBD-II port. West Des Moines installed a vehicle "T"-harness that connects other on-board vehicle systems on heavy-duty vehicles with the OBD port for integration with the GO9 system. The harness for heavy duty vehicles and an image of its installation is pictured in Figure 6. A different type of vehicle harness was provided by Geotab for light and medium duty vehicles.

Figure 5. Geotab GO9 Vehicle Hardware (Front and Back) for Vehicles with OBD-II Port

Figure 6. Geotab Vehicle T-Harness with 9-Pin Connector for Heavy Duty Vehicles

West Des Moines staff were responsible for the installation of the equipment on their fleet vehicles which was completed prior to the 2021 winter maintenance season. Geotab provided the City with installation guides and remote support to answer questions about issues with either the hardware or software. Geotab also provided training to the City staff on the web-based software. In addition, Geotab provided annual updates on new software features that could be used by the City if desired. The Geotab system would be utilized on West Des Moines vehicles for year round maintenance operations.

West Des Moines has connected a low pressure switch on their heavy duty vehicles for measuring the "up" and "down" state of snow plow blades. The switch is pictured in Figure 7 along with its installation on a heavy duty vehicle. The input from this switch is connected with the GO9 vehicle harness for the purpose of sending status data to the central software.

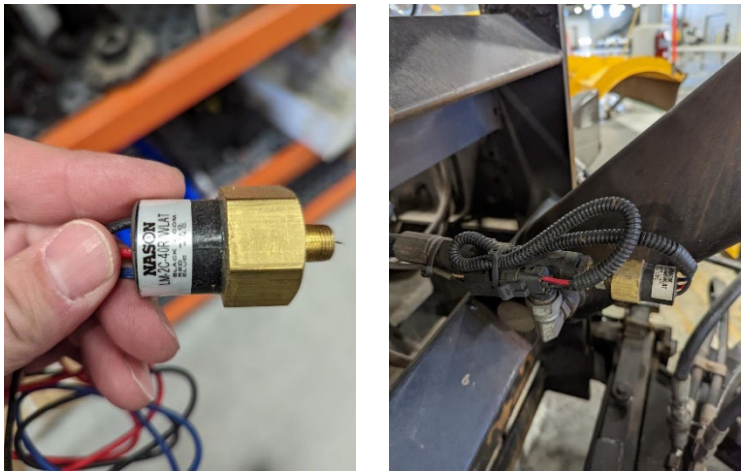


Figure 7. Low Pressure Switch for Plow Status on Heavy Duty Vehicles

West Des Moines has also received additional Geotab hardware for older vehicles that do not have an OBD-II port on the vehicles due to the age or type of vehicle. The device provides GPS tracking, accelerometer data, and ignition voltage primarily. An auxiliary cable can also be installed to gather additional data from the vehicles as needed.

West Des Moines also has 12 portable Geotab units that are battery powered and are provided to contractors that are responsible for winter maintenance snow plow operations. The Geotab units can report when a specific route has been completed by the contractor, and payment is issued based on the central software indicators that plow operators have completed operations in areas such neighborhood as cul-de-sacs. The portable units are only used in winter maintenance operations currently.
All Geotab GO9 devices communicate data from vehicles using a cellular modem that is built into the Geotab hardware, and no additional cellular antennae are required on the vehicles to communicate data from the vehicles. A web server that is managed by Geotab collects all data from vehicles and stores it for review by the City of West Des Moines.

4.3.4 West Des Moines System Software

West Des Moines utilizes the web-based central software provided by Geotab for viewing vehicle locations and for generating automated reports. Geotab allows for agencies to customize the map layout and other features of the central software to present only the information that is most relevant to the agency. Figure 8 shows a screenshot of the web-based central software that is used by West Des Moines.

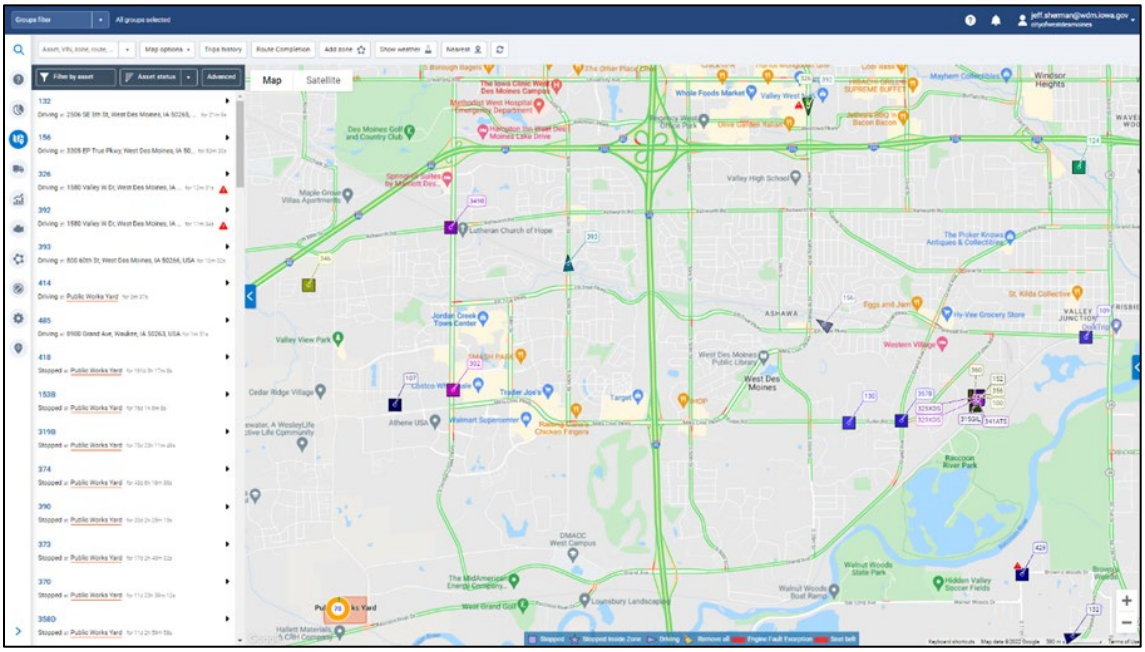


Figure 8. Screenshot of CompassCom Software Interface for Vehicle Tracking

During winter storm events, West Des Moines uses a route-completion component of the central software to communicate to the general public when plow routes have been completed. Vehicle location is not shared with the general public on a public facing webpage, but the route completion component does indicate which roads have been plowed. The City does not intend to use this route completion feature for non-winter maintenance activities. A screenshot of the interface is shown in Figure 9.

During a recent wind-storm, the AVL system was used to monitor vehicle locations that were responding to downed trees and other damage in real-time. This type of system use will aid the City during storm response year-round as well.

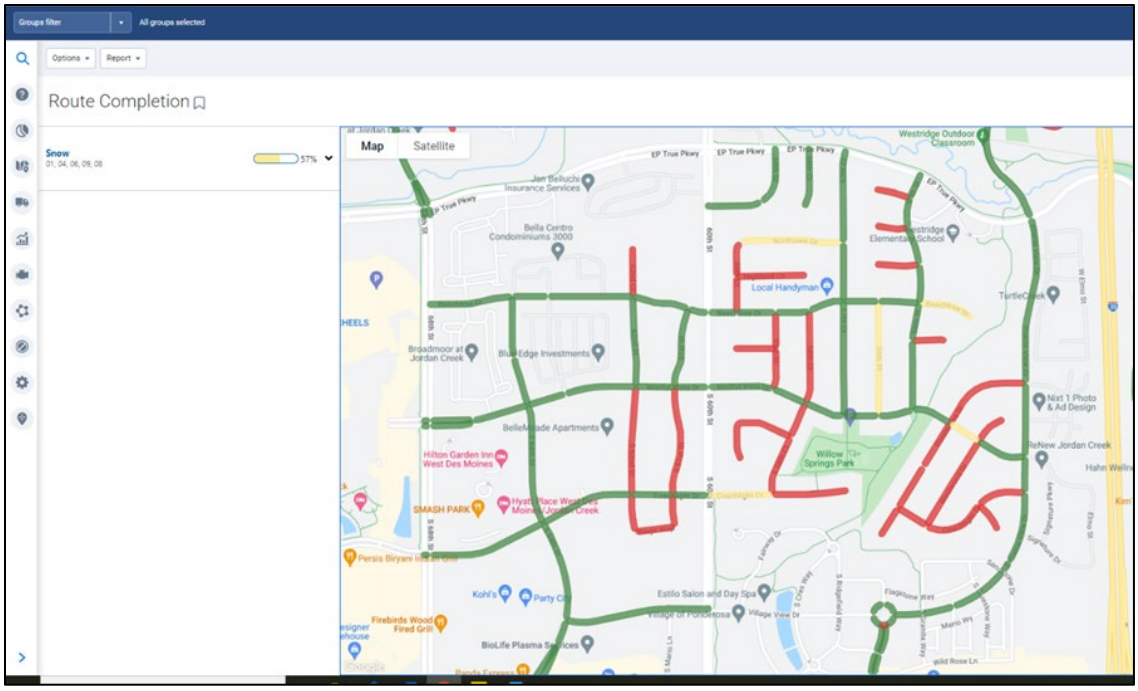


Figure 9. Screenshot of Route Completion Interface

4.3.5 West Des Moines Data Collection and Utilization

West Des Moines uses the Geotab GO9 system on its fleet of public works vehicles, which includes front loaders, graders, sweeper vehicles, paint trucks, light duty trucks, and snow plow vehicles. The GO9 vehicle hardware plugs into the OBD-II port on the vehicles which allows it to gather vehicle diagnostic and other information as desired by the City for each type of vehicle. For non-winter maintenance vehicles, vehicle location and mileage is the primary data collected. The use of a "T-harness" allows for integration of the GO9 unit with other vehicle systems. One example is understanding the "up/down" status of vehicle brooms on street sweeper vehicles. The central software can present what areas the vehicle has traveled with its brooms in a "down" state, which helps the City assess what areas have been treated over time.

West Des Moines noted that they were aware of other features of the system that would allow them to gather additional data such as usage of paint and herbicide. However, West Des Moines did not have an immediate plan for those additional features.

The central software can provide a number of customized reports for supervisors to review based on data collected by the vehicles. As the City gains more experience with the system over time, these reports can be created for supervisors on an automated basis for review when needed. Figure 10 shows an image of a seat belt usage report during a one week period in February 2022.

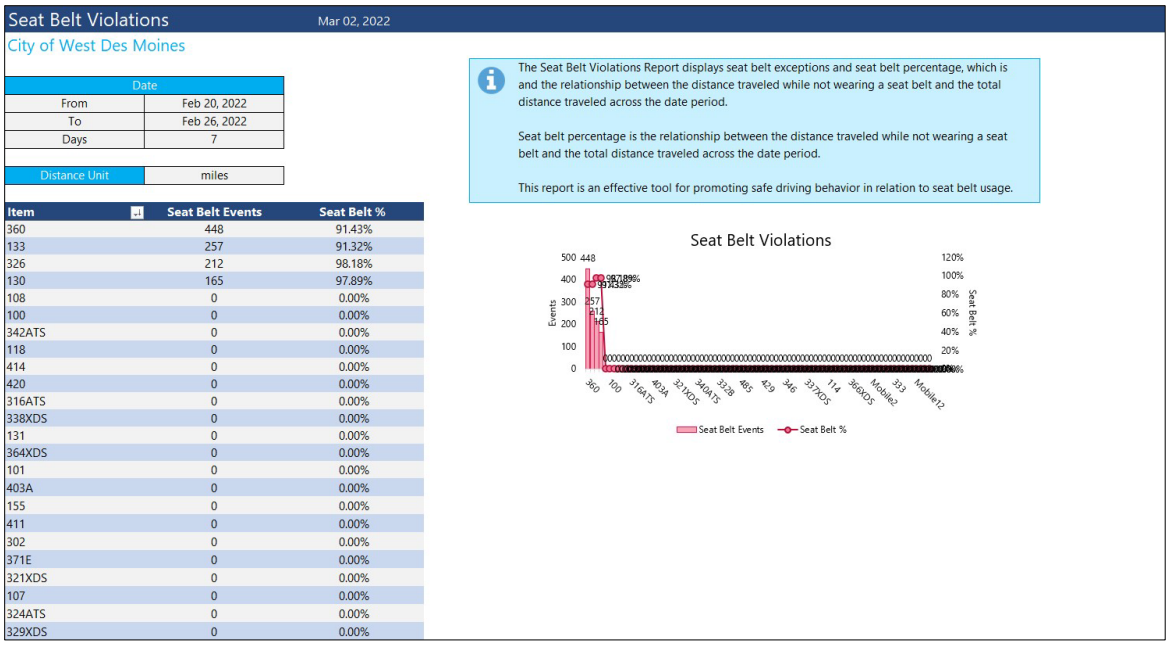


Figure 10. Seat Belt Usage Report

System data is stored by Geotab, and West Des Moines does not maintain a separate database to store the data. Users of the software can log into the system and request data for any period of time during prior operations.

West Des Moines views the AVL/GPS system as a tool that can help all staff better perform their operations. Vehicle operators are provided a username and password to the Geotab central software so that they can via their tablets on-board review the plow routes that they have completed during winter maintenance, which can also provide them data on how much material was used as well. Sharing access to the system software has also helped to ease "big brother" concerns from vehicle operators about the system being used in a disciplinary manner.

The City noted that this approach of sharing access to central software with vehicle operators could also have the same type of benefits for non-winter maintenance activities. This could apply well to street sweeping operations or other non-winter maintenance operations that require routes to be followed by vehicle operators.

4.3.6 West Des Moines System Benefits and Costs

A summary of the system costs provided through Sourcewell are provided in Table 10 .

Table 10. Hardware and Software Costs of City of West Des Moines AVL/GPS System

Items	Quantity	Unit Cost	Total Cost
Hardware			
Geotab GO9	95	$62.50	$5937.50
Accessories			
T-Harnesses for Heavy Duty Vehicles	27	$28.06	$757.62
T-Harnesses for Light and Medium Duty Vehicles	56	$28.06	$1571.36
Harnesses for Non-OBD-II Vehicle	12	$9.82	$117.84
IOX Works Cable GO9 to plow controller feedback	20	$122.40	$2448.00
Central Software Access	1	$0	$0
Sum of Hardware and Software			**$10,832.32**

A summary of the monthly service charges paid by the City are provided in Table 11.

Table 11. Monthly Service Charges for First Year of System Operations

Service Charges	Quantity	Unit Cost	Total Cost
Base Plan	74	$10.20/month	$754.80/month
Public Works Pro Plan	20	$30.60/month	$612.00/month
Sum of Monthly Service Charges			**$1,366.80 month**
Sum of Annual Service Charges			**$16,401.60/ year**

West Des Moines noted the following key benefits were observed:

- Reduction of liability and tort claims from the general public regarding their operations. One of the driving factors for the agency to utilize the AVL/GPS system for non-winter-maintenance purposes was to reduce liability and tort claims from the general public regarding their non-winter maintenance operations. The system has been used to locate where public works vehicles were on specific days in response to complaints from citizens regarding damage that may have been caused by those vehicles. City staff noted that some states place a greater liability on public works agencies than other states, which can be a good reason to justify the investment in an AVL/GPS system. The City sees this as one of the biggest benefits. Vehicle operators recognize that the system is a valuable tool to protect them, which also promotes their acceptance.
- Improved safety for vehicle operators. The system allows the City to observe if a vehicle is stopped at one location to an extended period of time which may be caused by issues related to vehicles or operators. The City can check on the operator for any problems.
- Reduction in Material Usage. The City has seen about a 25-30% reduction in the amount of salt used with the AVL/GPS system in place.

4.3.7 West Des Moines System Issues and Challenges

Institutional Issues

City staff noted that providing vehicle operators a username and password to the Geotab central software for monitoring their performance has helped to ease "big brother" concerns from vehicle operators about the system being used by supervisors in a disciplinary manner.

Technological Issues

No technological issues with the Geotab system were observed in the first year of its operation.

Implementation Issues

Since moving to the Geotab GO9 system, City staff have primarily been responsible for the installation of the AVL system for their vehicle fleet. Vehicle mechanics can plug the GO9 hardware into the OBD-II port, and they can also connect the T-harness to the GO9 hardware. Additional connections from the T-harness to other vehicle systems were performed by vehicle mechanics. The City obtained adapters for their heavy truck vehicles to connect with the "up/down" sensor on the vehicles, and this connection was the most time-consuming with the overall system installation.

4.3.8 West Des Moines Lessons Learned

The following are additional observations and lessons learned:

- City staff encourage other agencies interested in AVL/GPS procurement to do their homework first on what they need from the system, as well as some homework on the company that they are interested in as well. Reviewing agency needs with respect to winter and non-winter maintenance operations can lead to the development of system specifications and a scope of work for an AVL/GPS vendor. Agencies may also review how other peer agencies have implemented systems to improve their winter and non-winter maintenance operations to gather additional ideas on how to prove upon their own operations. Deciding upfront what data to collect and utilize for the agency helps to set expectations; however, too much data could create overload on supervisors.
- West Des Moines has seen AVL/GPS systems starting to move towards more of a plug-and-play type of system similar to how Geotab is being used by the City. The flexibility is allowed through use of the OBD-II port and the T-harness to connect with any type of system on the vehicle that the City desires. The prior system utilized by the City was more proprietary and required greater time and resources to maintain.
- Providing vehicle operators access to the system helps them to realize the benefits and minimize the "big brother" syndrome. Educating staff about how the information gathered by the system will be used is also important.
- Having a champion to manage the program is critical. There will be technical, software, integration and other issues. It is important to have someone knowledgeable and proactive in working toward alleviating issues.

4.4 Case Study 3: City of Farmington Hills Public Works Department

4.4.1 Agency Overview and AVL/GPS Project Background

The City of Farmington Hills is located in the north and west of Detroit, Michigan. Figure 11 shows an outline of the city limits and location. Farmington Hills has installed an AVL/GPS system manufactured by SkyHawk Telematics (SkyHawk) on all of the vehicles in their fleet. The system has been used since 2017, and the city is now using the second version of the system that was previously updated by SkyHawk. Prior to 2017, Farmington Hills used Motorola two-way GPS radios that were limited to either the use of voice or data at one time to support maintenance operations. The City desired to purchase a system that could communicate data in real-time on vehicle location which would be viewable on map-based interface, as well as a system that could be upgraded as cellular technology evolved over time. In addition, Farmington Hills wanted to integrate an AVL/GPS system with the RexRoth CS550 spreader controllers in use on those types of vehicles to allow the City to track materials used during winter weather events.

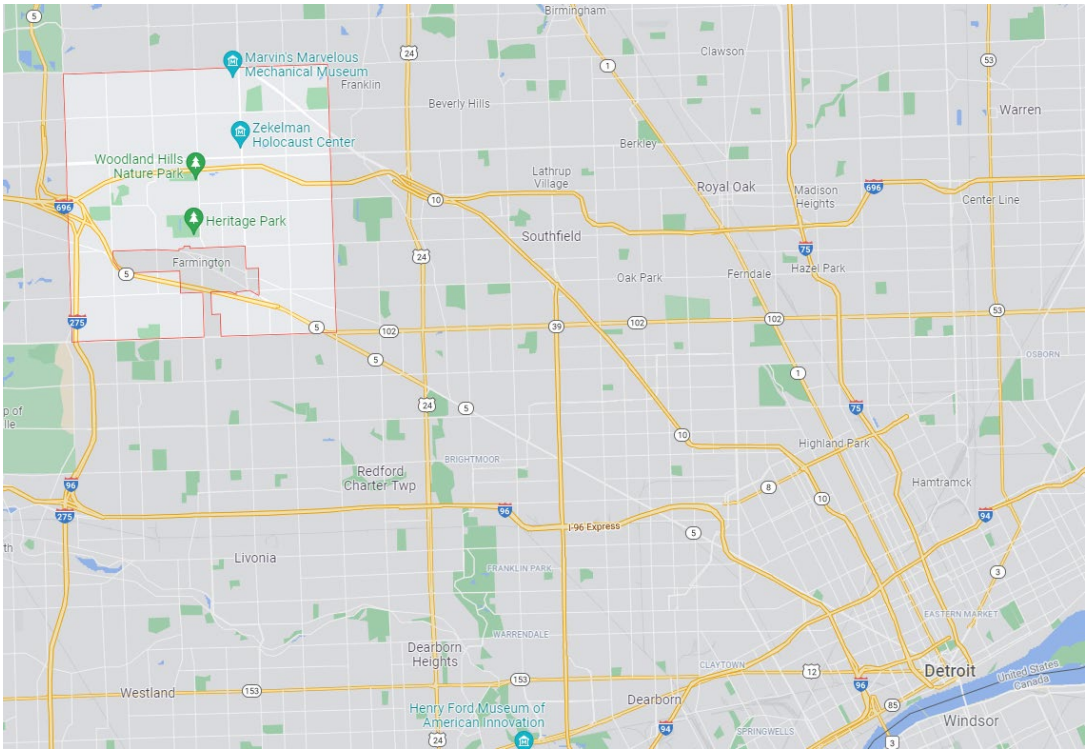


Figure 11. City of Farmington Hills, Michigan
Source: Google Maps

In addition to winter maintenance operations (snow and ice removal), Farmington Hills performs the following types of non-winter maintenance operations:

- Gravel road maintenance. Farmington Hills maintains about 22 miles of gravel residential roads with these vehicles. City vehicles are used to grade the roads, add road gravel where needed, and can treat the roads with a dust control product.
- Roadside mowing along City roads.

- Street sweeper maintenance. There are three portable AVL/GPS devices that are provided to a separate contractor for them to use during street sweeping operations.

4.4.2 Farmington Hills System Procurement

Farmington Hills solicited for bids and received three responses from AVL/GPS system vendors. The City evaluated all three bids with regard to price and adherence to the project specifications included within the solicitation. SkyHawk was selected based on its capability of integrating with the RexRoth spreader controllers. Given that the City's vehicles are used on a year-round basis, the AVL/GPS system has also been actively used by the City for non-winter maintenance operations.

4.4.3 Farmington Hills System Implementation and Integration

Farmington Hills uses SkyHawk AVL/GPS equipment on three different types of maintenance vehicles in both winter and non-winter months:

- About 15-16 heavy duty trucks are equipped with plows, salt spreaders and liquid tanks used for roadway deicing in winter weather months. These vehicles are used in non-winter months for gravel roadway maintenance (i.e. surface floating of gravel roads and dust countermeasures), street sweeping and other road maintenance purposes.
- Between 15 and 20 additional trucks are used for general snow plowing in winter months and general road maintenance use in non-winter months.
- Three portable AVL/GPS units are used with street sweeper vehicles that are operated by a contractor.

Staff from SkyHawk initially traveled to the City's maintenance facility to train mechanics on the process of hardware installation in vehicles. City staff followed the process and completed the remaining installations on all vehicles. When older vehicles are scheduled for replacement, City staff will remove the AVL/GPS equipment from them and install it on new vehicles. New vehicles are pre-wired by the vehicle manufacturer which allows for straightforward installation and integration of the AVL/GPS system.

The AVL/GPS units are all hard-wired into the City's vehicles and are not transferred between different groups of vehicles, with the exception of the portable AVL/GPS units used by contractor's assisting with street sweeper vehicles.

The SkyHawk hardware device installed on Farmington Hills heavy and medium duty vehicles is shown in Figure 12. A metal enclosure is placed in the heavy duty trucks that are equipped for snow plowing and used as dump trucks for non-winter maintenance. A sealed clear enclosure is used with medium duty trucks. The enclosures help to stabilize the equipment and keep it protected from any damage that could be caused from liquids or other equipment inside the vehicle.

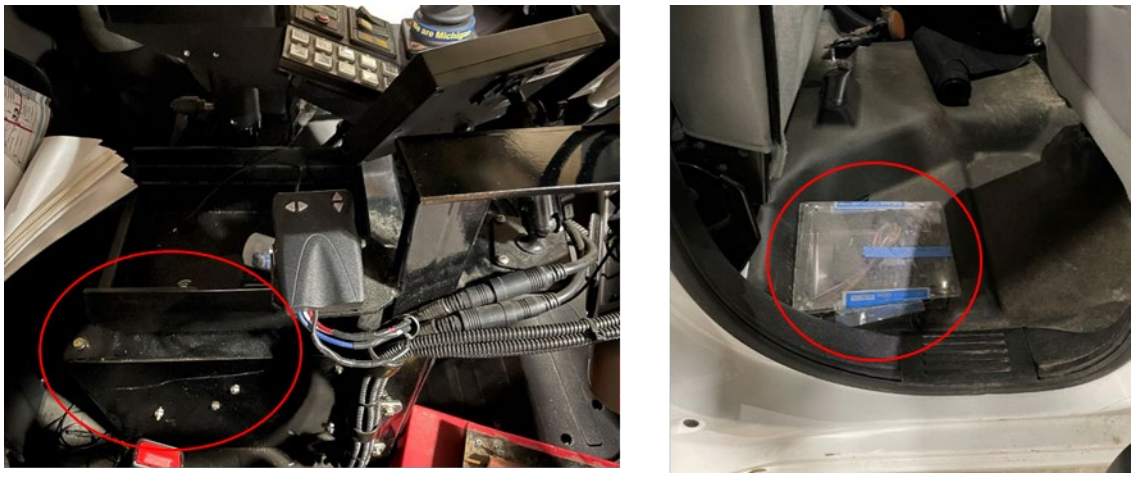


Figure 12. SkyHawk Vehicle Hardware (circled) for Heavy and Medium Duty Vehicles

An interior puck-like antenna is installed inside the dash of the vehicles. Larger trucks have a small exterior antenna that is hard-wired to the AVL/GPS system in the vehicle. The vehicle antennae are displayed in Figure 13. Portable AVL/GPS units that are provided to contractors for street sweeping operations are displayed in Figure 14.

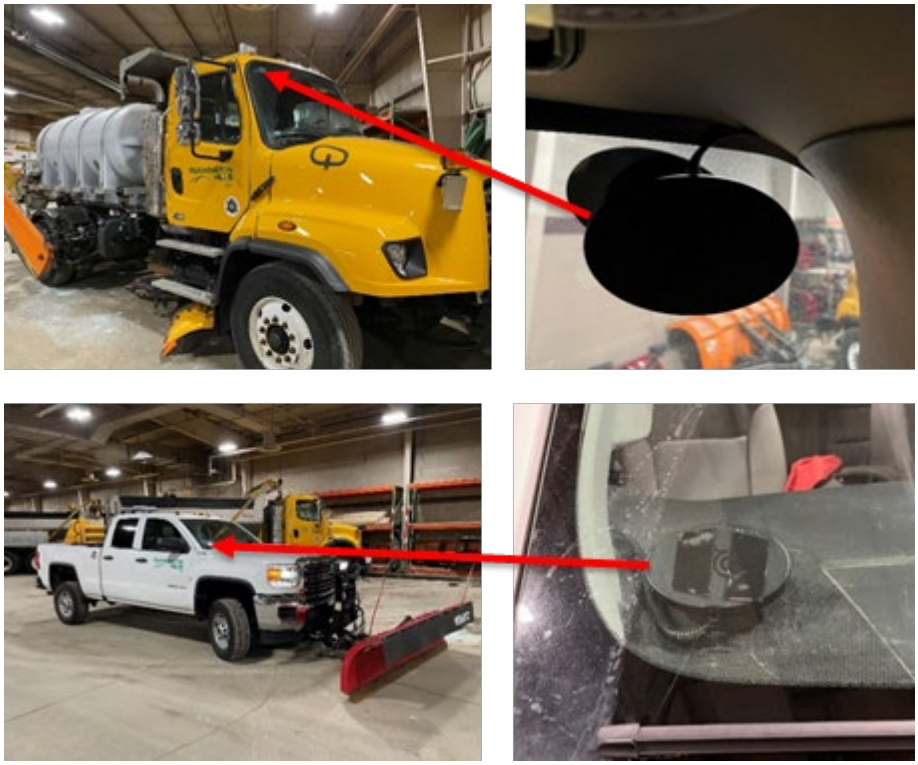


Figure 13. SkyHawk Vehicle Antennae for Maintenance Vehicles

Figure 14. SkyHawk Portable AVL Equipment for Street Sweeper Vehicles

4.4.4 Farmington Hills System Software

Farmington Hills utilizes the web-based SkyHawk central software for viewing vehicle locations, monitoring operational status, and generating reports. The map layout and other features of the central software can be customized to present only the information that is relevant to the City. Figure 15 shows a screenshot of the web-based central software that presents an overview of all vehicles operating within a select area of the map. Individual vehicles can be selected to view additional information specific to that vehicle, as shown in Figure 16. Data on vehicle locations is not shared with the general public during either winter or non-winter periods of the year. Farmington Hills uses the central software to monitor what roads have been treated by vehicles during winter weather events, and they assign a one-word status message to roadways as "pending" / "underway" / "completed" on the public-facing City website to inform residents of road treatment status.

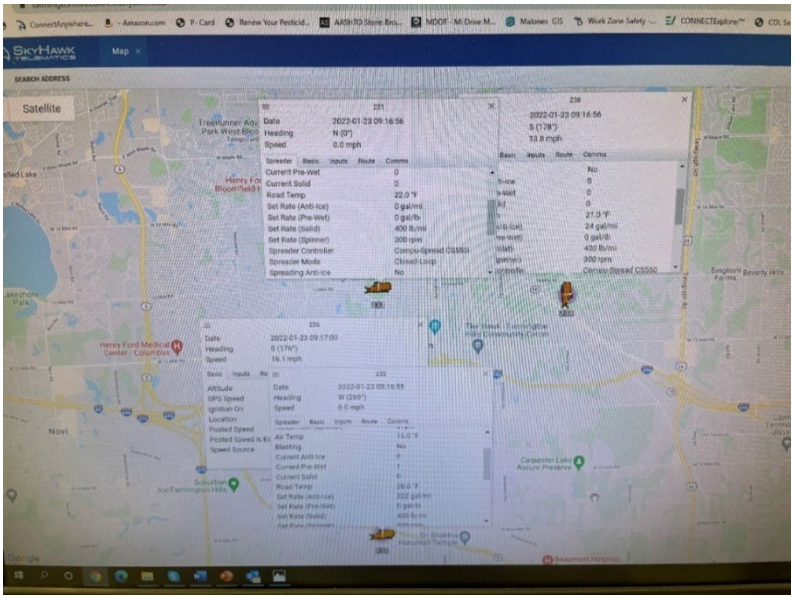


Figure 15. Screenshot of SkyHawk Software Interface

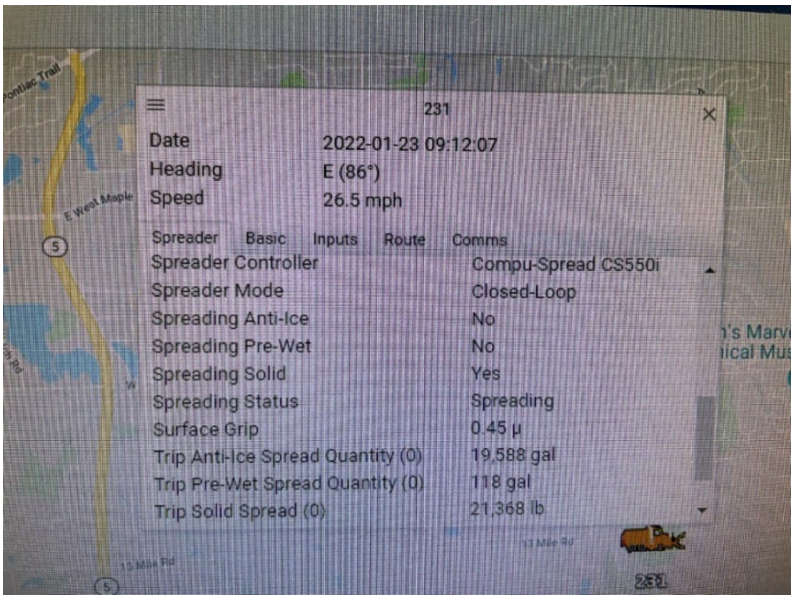


Figure 16. Screenshot of SkyHawk Software Interface with Vehicle Data

4.4.5 Farmington Hills Data Collection and Utilization

A summary of the data collected by the City on non-winter maintenance operations is presented in Table 12.

Table 12. Types of Non-Winter Maintenance Operations AVL/GPS Data Collected

AVL/GPS Data	Type of Non-Winter Maintenance Operations
Vehicle Location Data	General Road Maintenance Street Sweeping Operations
Vehicle Heading and Speed	General Road Maintenance Street Sweeping Operations
Spreader Controller Status	General Road Maintenance

System data is stored by SkyHawk and the City does not maintain a separate database to store AVL/GPS system data. Data collection from vehicles is automated through use of the software interface. It does not require staffing and resources of the City to collect and manage the data. Users of the software can log into the system and request data for any period of time during prior operations. Given that supervisors can access the data when needed, the current level of staffing and resources is adequate to support the operations.

The AVL/GPS system has been used to respond to complaints from residents regarding their operations, which happens all year round. City staff use the central software interface to illustrate to residents where their vehicles were operating during any period of the day.

The City recognized that there are many features of the AVL/GPS system that the City are not used currently. These include connecting the SkyHawk equipment in the vehicle to plow and street sweeper equipment to gather up/down status of cutting edges or sweeper brooms, as well as roadside mowers to determine whether or not mowers are actively mowing in the field. In addition, the RexRoth spreader controller is also used for liquid applications during non-winter months, and the AVL/GPS system can help measure the amount of liquid applied during non-winter operations for dust controller or other liquid application tasks. Another use case of the up/down status indicator can be to gather the hours of use in which a plow cutting edge or a sweeper broom was in the down state. This can help to determine the effective life span of a sweeper broom, since the bristles on the broom are known to deteriorate over time.

The City does not utilize many of the reporting features and other measures the system offers. Some of these measures are not needed for the City's current operations, although that may change in the future.

4.4.6 Farmington Hills System Benefits and Costs

A summary of the SkyHawk equipment costs provided by the City are in Table 13 .

Table 13. Hardware and Software Costs of City of Farmington Hills AVL/GPS System

Items	Quantity	Unit Cost	Total Cost
Hardware			
SkyHawk Hardware (including spreader integration)	17 vehicles	$975.00	$16,575.00
Proximity Plow Sensors (All Vehicles)	17 vehicles	$78.00	$1,326.00
Installation Costs for Heavy Duty Vehicles	17 vehicles	$320.00	$5,440.00
Light Duty Vehicle Hardware	28 vehicles	$335.00	$9,380.00
Installation Costs for Light Duty Vehicles	28 vehicles	$120.00	$3,360.00
Central Software Access	1	$0.00	$0.00
Sum of Hardware and Software			**$36,081.00**

Table 14 presents the annual service fees and cellular service fees the City contracted for with SkyHawk.

Table 14. Annual Service Fees and Cellular Fees for System Operations

Items	Quantity	Unit Cost	Total Cost
Monthly Service Fees			
Winter Operations Heavy Duty Vehicles	17 vehicles	$21.50/month	$365.50
Track and Trace Light Duty Vehicles	25 vehicles	$12.00/month	$300.00
Annual Total (12 Months)			**$7,986.00**
Monthly Cellular Fees			
Winter Operations Heavy Duty Vehicles	17 vehicles	$7.50/month	$127.50

Items	Quantity	Unit Cost	Total Cost
Track and Trace Light Duty Vehicles	25 vehicles	$3.50/month	$87.50
Annual Total (12 Months)			**$2,580.00**
Sum of Annual Service Fees and Cellular Fees			**$10,566.00**

Table 15 presents additional project management, website setup, and training costs Farmington Hills paid for the system.

Table 15. Project Management and Setup Fees for System Operations

Items	Quantity	Unit Cost	Total Cost
Project Management / Website Setup Fees	1	$10,000	$10,000.00
Software User Training	1	$1,500	$1,500.00
Project Management Total			**$11,500.00**

Farmington Hills stated three key areas of benefits that have been observed through the use of AVL/GPS system:

- Safety: In case of unforeseen safety issues or a staff emergency, the system allows the supervisors to know the vehicle and operator locations and respond to the situations quickly.
- Speed Compliance: Residents may complain about maintenance vehicles being speeding. The system allows the City to verify the speed of the vehicles to respond to complaints as well as promote operators to be in compliance of speed limits.
- Citizen Complaints: In addition to speed compliance, residents may complain that City vehicles were either trespassing or causing damage to private properties. City staff use the central software interface to illustrate to residents where their vehicles were operating during any period of the day.

4.4.7 Farmington Hills System Issues and Challenges

Institutional Issues

There were concerns from vehicle operators and their union about whether the AVL/GPS system would be used for disciplinary purposes. City staff were able to communicate that the system would only be used for data collection purposes, and there was a written agreement with the union that served as a compromise on how the system would be used. Over time, vehicle operators have not expressed the same concerns given that the system can be used to exonerate them from complaints by the general public.

Technological Issues

An initial technological concern was the evolution of cellular technology. The AVL/GPS system is capable of upgrading its cellular capability as networks transition from 3G to 4G service, or from 4G to 5G service over time. This is accomplished by plugging a separate cellular card into the SkyHawk vehicle hardware.

Implementation Issues

Farmington Hills did not experience issues with procurement or implementation of the AVL/GPS system. New vehicles are pre-wired by the vehicle manufacturer which makes the installation and integration of the AVL/GPS system fairly straightforward.

4.4.8 Farmington Hills Lessons Learned

The following lessons learned are offered based on the City of Farmington Hills case study:

- AVL/GPS systems can have a great amount of safety benefit for maintenance departments on a year round basis. The system can quickly report on vehicle and operator locations in the event of an emergency, and can also report on vehicle speeds in the event of citizen complaints about vehicles that may have been driving too fast in a neighborhood.
- AVL/GPS systems can be an effective tool protecting public agencies and their vehicle operators from tort claims and liability issues in the event of citizen complaints about vehicles that may have caused damage to personal properties. The City of Farmington Hills receives more citizen complaints on property damages during non-winter months, which further supports their use of the AVL/GPS system on maintenance vehicles for a year round basis.
- The City communicated the primary needs of its agency with respect to AVL/GPS technology and the need to integrate with a specific type of spreader controller. Despite the needs being related to winter maintenance, the AVL/GPS system has still proven valuable to the City on a year-round basis to support street sweeping operations, maintaining gravel roads and other summer road maintenance activities.

4.5 Case Study 4: Illinois DOT

4.5.1 Agency Overview and AVL/GPS Project Background

Illinois DOT (IDOT) operates with its central office headquarters in Springfield, IL and five transportation regions across the state. Within the five regions, there are a total of nine highway districts that are located to best assess and oversee Illinois' transportation infrastructure. Throughout each region, IDOT strives to accomplish its primary objectives through the planning and programming of road, bridge, public transportation, rail and aviation projects. These objectives include preservation and maintenance of all existing transportation systems, upgrades to existing facilities as needed, and system expansion across all modes. A map of the IDOT regions and districts is presented in Figure 17.

IDOT's AVL/GPS system includes vehicle radio hardware from Motorola Solutions (Motorola) for the purpose of sending voice and data from the vehicles back to a central office location. Motorola had previously entered into a public/private partnership with the state of Illinois to develop a statewide trunk radio network referred to as STARCOM 21 (STAte Radio (Voice) COMmunications for the 21st Century). The STARCOM 21 network is owned and operated by Motorola and currently serves more than 45,000 radio subscribers from various State, local and federal government and non-governmental entities.

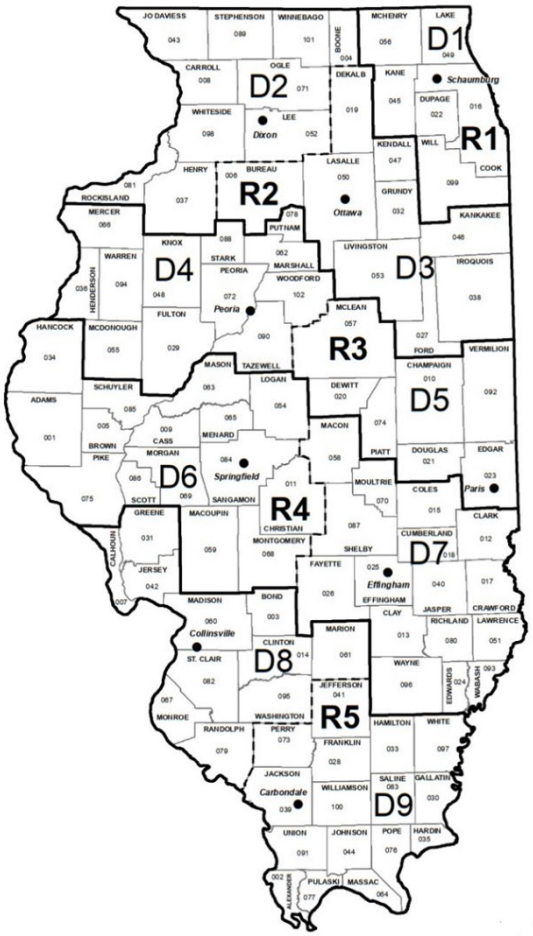


Figure 17. IDOT Regions and Districts
Source: Illinois DOT

The network is a statewide, 700/800 MHz, Project 25-compliant, digital, trunked voice radio network that is open to all public safety and public service agencies in the State of Illinois. As the network grew over time in terms of size and subscribers, IDOT reviewed the potential for using radio communications for transmitting both voice and data over the network to serve vehicle fleet operations. IDOT staff noted that there were multiple cellular providers that had strong coverage in metro areas of the state, but this would have meant having to manage multiple cellular contracts over time. There were also gaps in cellular coverage in areas of the state at the time, and the option to use the radio network offered the greatest amount of coverage.

IDOT had approximately 4,500 maintenance vehicles in use throughout the state that are equipped with Motorola radio hardware in their vehicles. In addition to winter maintenance vehicles, this includes paint striping trucks, sign shop trucks, portable scale trucks, and water pumps for use during non-winter maintenance operations.

4.5.2 IDOT System Procurement

IDOT utilized a statewide procurement contract to purchase Motorola radio equipment in 2016 for their AVL/GPS system. This also allowed IDOT to utilize the STARCOM 21 radio network for data and voice communications from their vehicles back to a central server location.

4.5.3 IDOT System Implementation and Integration

A demonstration with winter maintenance vehicles in District 5 (Champaign-Urbana area) was first performed with the Motorola system. IDOT learned through this demonstration that, to avoid potential conflicts with voice transmissions, it was ideal to send GPS data and other data from the vehicles through the radio network at 5-minute intervals. Non-winter maintenance operations could send their data through the network at 2-3-minute intervals. Based on the pilot findings, Motorola performed data tests and made adjustments to allow for higher amounts of data transmissions.

After the demonstration in District 5 was completed, IDOT expanded the installation to other districts throughout the state and made any modifications as needed to the installation. The overall rollout process took about three to four years and was completed in 2020.

The IDOT AVL/GPS system includes the following hardware equipment:

- Vehicle radio units from Motorola (APX model 6500 and others) are installed in the vehicle for radio-based communications of both voice and data from the vehicles. The front view of the radio is displayed on the left side in Figure 18 with a solid satellite icon meaning that a GPS lock has been obtained. A rear view is displayed on the right side in Figure 18 showing the GPS antenna connection below the power line.
- Two different types of GPS antennae are pictured in Figure 19. The image on the left displays a pillar arm GPS antenna that is installed inside the cab of a truck and is used in snow and non-snow maintenance vehicles for vehicle tracking. An exterior, roof-mounted GPS antenna is pictured on the right and is used in non-snow maintenance vehicles for tracking.
- A hand-held Motorola APX6000 used in a select number of vehicles for GPS tracking purposes is shown in Figure 20 (front and back views). This is used for vehicles that transport portable commercial vehicle scales for commercial vehicle weight enforcement, as well as for Emergency Patrol Vehicles (EPVs) in IDOT District 8 in the St. Louis area.
- A LMU 4233H model, as displayed in Figure 21, is equipped on winter maintenance vehicles for snow and ice treatment and Emergency Traffic Patrol (ETP) vehicles in IDOT District 1. The spreader controller cable (not shown) is the same 5 pin cable to DB9 serial cable just like the radio interface cable. The engine diagnostic port DB15 is not used by IDOT. The Aux I/O 22 pin plug is the connection of the plow up/down tilt switch and PTO on/off for the ETP truck and carriage up/down switch on the paint stripers. Power cable is the connection of 12/24vdc and ground.
- A Cal-Amp TTU2830 GPS unit is installed on IDOT water pumps that are distributed to flooded areas of the state. The GPS unit monitors the location of the pump, and it can also return the number of hours that the pump has been operational.

Front View Back View

Figure 18. Motorola APX 6500 800 MHZ P25 Radio Unit

Figure 19. Interior (left) and Exterior (right) Antennae with IDOT Maintenance Vehicles

Figure 20. Motorola APX6000 Units for Portable Scale Vehicles and Emergency Patrol Vehicles

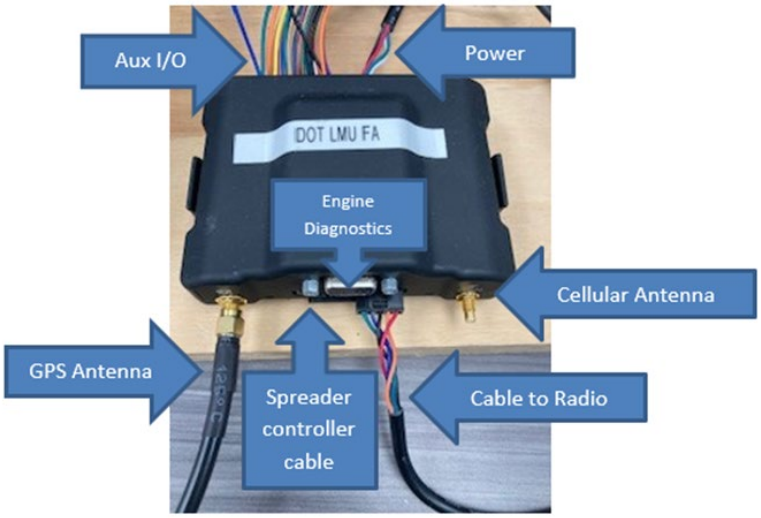


Figure 21. Cal-Amp Units for Winter Maintenance Vehicles and Emergency Traffic Patrol Vehicles

Regarding the installation of AVL/GPS equipment, IDOT has a radio maintenance contract with Motorola who has various radio shops as subcontractors throughout the state for the installation of Motorola radio equipment in those vehicles. Most of these installations are fairly simple to complete. Radio equipment is placed in the appropriate location for each type of vehicle and can vary based on vehicle type. All equipment installed in the vehicle is dedicated to each vehicle and does not get transferred to other vehicles.

Larger winter maintenance vehicles are pre-wired by a vehicle manufacturer so that radio shop technicians can insert the radio equipment when the vehicle arrives for use. As older maintenance vehicles are phased out of the fleet, radio shop technicians will remove the Motorola radio, AVL equipment and place it inside the newer replacement vehicles that arrive pre-wired from the manufacturer.

4.5.4 IDOT System Software

IDOT has implemented a web-based central software package from CompassCom as the interface that is viewed by agencies responsible for managing vehicle fleets and other equipment throughout the state. Software users can perform a customization of the interface to view only the information that is useful for them. There was about 4 years' worth of AVL/GPS data available to system users through the software as of January 2022. Older data was off-loaded onto an external hard drive for longer term storage.

For winter maintenance, IDOT has developed a web-based dashboard through CompassCom that can present several types of operational information for supervisors to monitor during snow events. This includes the number of vehicles that are in operation, how many are spreading materials, how much salt has been dispensed, and other information. A similar type of data dashboard could also be developed to support non-winter maintenance operations if needed.

Figure 22 presents an image of the northern part of Illinois and the non-snow fleet in operation on February 7, 2022. Different vehicle icons indicate differing types of equipment in use. ETP vehicles in

District 1 (Chicago area) are represented with different colored chevrons in the upper right part of the image. The icon color will change on the map in correlation with telemetry status change or with the radio being active.

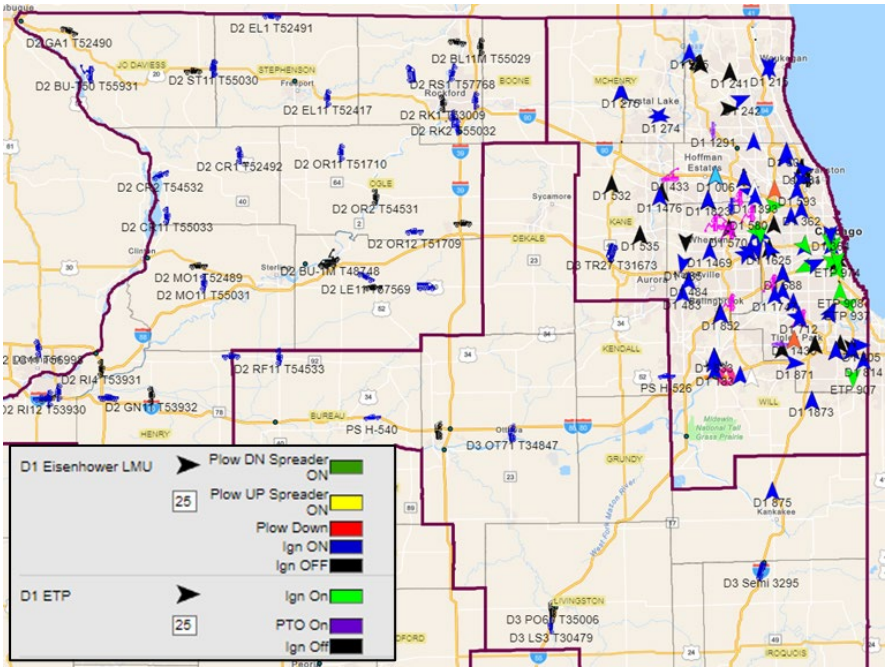


Figure 22. District Level View of Non-Winter Maintenance Fleet (North Part of Illinois)

IDOT also uses the software interface to track and manage paint truck operations. Figure 23 presents an image of a historical replay of the full route of an IDOT District 6 paint striper truck that was taken on October 21, 2021.

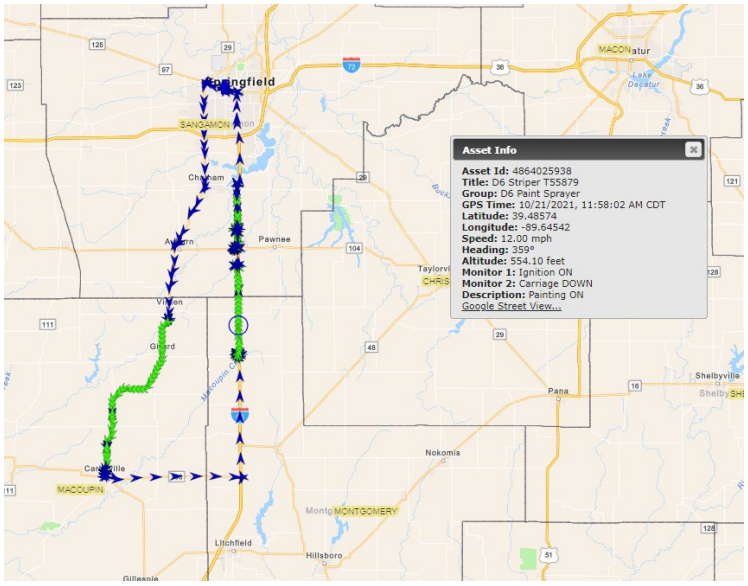


Figure 23. IDOT District 6 Paint Striper Tracking Historical Replay of Full Route

Water pump operations can also be tracked and managed through the software interface. IDOT can view the location and operational status (i.e. engine running or off) of a water pump that has been distributed to a flooded area. IDOT can use the software to track hours of pump use for general maintenance purpose and to confirm the location of the pump over time in case the pump is moved since delivery and setup. Figure 24 illustrates a report generated by CompassCom software that shows the water pump ran for a total of 168 hours and 50 minutes from July 2 through July 15, 2021.

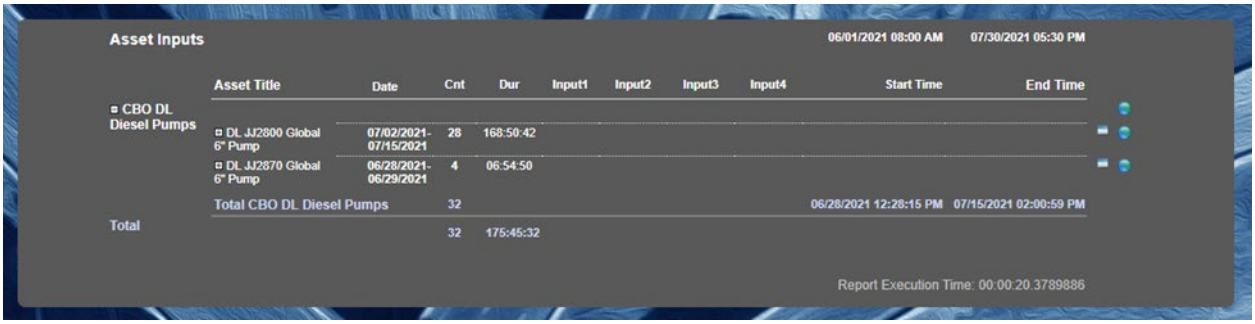


Figure 24. IDOT Diesel Powered Water Pump Status and Usage Report

IDOT has integrated data from RWIS environmental stations into the CompassCom software to provide real-time weather data, as well as data from river gauges that can indicate river heights in areas that frequently experience flooding conditions. In addition to CompassCom, IDOT also uses tablet software from Neotreks which has only used with winter maintenance vehicles to transmit camera images taken from tablets in the vehicle of road conditions and sent over a cellular network. This software is being tested in one IDOT district. Based on the results of the demonstration, IDOT will reach out to other districts to gauge a level of interest in expanding use of the software throughout the state.

4.5.5 IDOT Data Collection and Utilization

A summary of the data collected by IDOT on non-winter maintenance operations is presented in Table 16.

Table 16. Types of Non-Winter Maintenance Operations AVL/GPS Data Collected

AVL/GPS Data	Type of Non-Winter Maintenance Operations
Vehicle Location Data Vehicle Location Alarm Notifications	IDOT maintenance vehicles ETP/EPV operations Paint striping operations Sand-bagging operations (during flooding season) Portable scales for vehicle weight enforcement Sign shop trucks
Vehicle Tow Active	ETP operations
Striping On/Off	Paint striping operations
Water pump location	Flood pumping operations (during flooding season)
Hours of water pump operations	Flood pumping operations (during flooding season)

As noted earlier, IDOT staff can view the data collected through the CompassCom central software. Individual users are granted access to the software and given access to view only the vehicles that pertain to their department.

The use of the AVL/GPS system is customized to each district and agency. The individual uses of the system data are described below:

- Paint Striping Operations: Trucks are monitored to determine when paint striping began and when it ended on a specific date. There was discussion about a pilot project in District 6 to capture additional data on the amount and type of paint used by the vehicles.
- Sign Shop Operations: Vehicle locations can be monitored by supervisors to assess progress in sign replacements in the field.
- Emergency Response Support: Field staff can monitor vehicle locations that support sand-bagging operations during flood season as they approach locations where sand bags are loaded onto those vehicles. This allows for an improved field operation to speed up the process of loading necessary resources onto those vehicles.
- Water Pump Monitoring/Usage: A GPS unit is placed on water pumps to monitor the location of the pump and verify that it has not been moved. The unit can return the number of hours that the pump has been operational. IDOT uses the hours of service to determine when water pumps may need to be replaced with new ones. Alerts can also be set to communicate to the operational staff on when the pumps has been operating excessively.
- Incident Response Support: Illinois State Police (ISP) can request assistance from maintenance vehicles to respond to roadway incidents. Dispatchers in the IDOT ComCenter can use CompassCom software to monitor for the location of the nearest vehicles and provide updates to ISP on the estimated time of arrival of those vehicles.
- Emergency Traffic Patrol (ETP) / Emergency Patrol Vehicle (EPV): These fleets respond to stalled vehicles and other incidents along roadways in the Chicago area and the St. Louis metro east area of the state. If vehicles need to be towed, the radio equipment is connected with the tow mechanism on the ETP vehicle, which allows supervisors to see that a vehicle has been towed from one area to a specific yard location.
- Commercial Vehicle Weight Enforcement Support: Supervisors monitor the location of vehicles that distribute portable scales to support weight enforcement and respond to requests from ISP for portable scales and enforcement. Vehicles are equipped with both a Motorola radio and a unit that is GPS capable.

4.5.6 IDOT System Benefits and Costs

Motorola radio hardware from the vendor costs approximately $5,000 per device, and the antenna for communications costs about $50. The costs from Motorola for this equipment were also discounted given that such a large amount of devices were procured. The overall cost for system maintenance is approximately $900,000 on an annual basis. This includes maintenance of the Motorola vehicle hardware, the AVL data server, the CompassCom software application, and any other AVL/GPS equipment procured from Motorola.

A driving factor for procuring the AVL/GPS system was safety of vehicle operators. Through the use of a push button on the vehicle radio, vehicle location can be sent instantly to supervisors that can be alerted to a safety concern reported by vehicle operators. The supervisor can then communicate with the operator over the radio system to determine how best to respond. If the operator is not responding to the radio calls, the supervisor can send help to the location to check on the operator.

The AVL/GPS system has also been used to address public complaints regarding property damage from IDOT vehicles. With the software, IDOT can verify the locations of IDOT vehicles at the time of the reported issue to confirm whether an IDOT vehicle was involved or not.

The ability to document the amount of emergency response and support provided during flooding season has also been a big benefit to the use of the system for non-winter maintenance operations.

In the spring of 2020 at the height of the COVID-19 pandemic, IDOT was responsible for the delivery of medical supplies throughout the State from a central warehouse location. The AVL/GPS system allowed IDOT for tracking incoming truck convoys from the Districts to pick up medical supplies. With the advanced knowledge of when and which District would arrive next, warehouse personnel would have the shipment ready for the trucks. This greatly decreased the wait time of loading the trucks and got the convoys back on the road with the much needed medical supplies.

4.5.7 IDOT Issues and Challenges

Institutional Issues

There were some initial "big brother" concerns from vehicle operators over the AVL/GPS system. An agreement was developed with the union that noted the system would not be used to initiate discipline by supervisors, but would only be used to investigate incidents if needed. Concerns have also eased over time as the system has been used to address public complaints regarding property damage from IDOT vehicles. With the software, IDOT can verify the locations of IDOT vehicles at the time of the reported issue to confirm whether an IDOT vehicle was involved or not.

Other Issues

IDOT did not experience issues related to procurement, installation, implementation, operations or maintenance of the AVL/GPS system.

4.5.8 IDOT Lessons Learned

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

- Start the deployment of the AVL/GPS system where there is "buy-in" and support in place for the project. As the concept is proven, build out from there to support other areas. In addition, new use cases/applications of the AVL/GPS system can be proposed by a district and tested there prior to expanding the use to other districts. This has proven beneficial for the agency in determining use cases for the AVL/GPS system to support different types of non-winter maintenance activities.

- The ability to document the amount of emergency response and support provided during flooding season has been a big benefit to the use of the system for non-winter maintenance operations.
- IDOT noted that their approach to AVL/GPS deployment for their fleet was to procure the equipment first and address various needs from districts and internal agencies as they arose over time. While the system has proven very beneficial, an alternate approach of determining agency needs first, followed by procurement, might be a more desirable approach for agencies that are considering a similar type of AVL/GPS deployment.

4.6 Case Study 4: Alabama DOT

4.6.1 Agency Overview and AVL/GPS Project Background

ALDOT is divided into five regions as shown in Figure 25. Each ALDOT district contains a maintenance superintendent and a maintenance supervisor responsible for non-winter maintenance operations. ALDOT operates a fleet of herbicide spray vehicles to support the mission of ALDOT's vegetation management program, which is to provide safe and aesthetically pleasing travel ways throughout the state. ALDOT also operates a larger fleet of other vehicle types (light-weight vehicles, maintenance vehicles / trucks) on a statewide basis and had a separate need to track vehicle mileage for determining when vehicle maintenance should be scheduled.

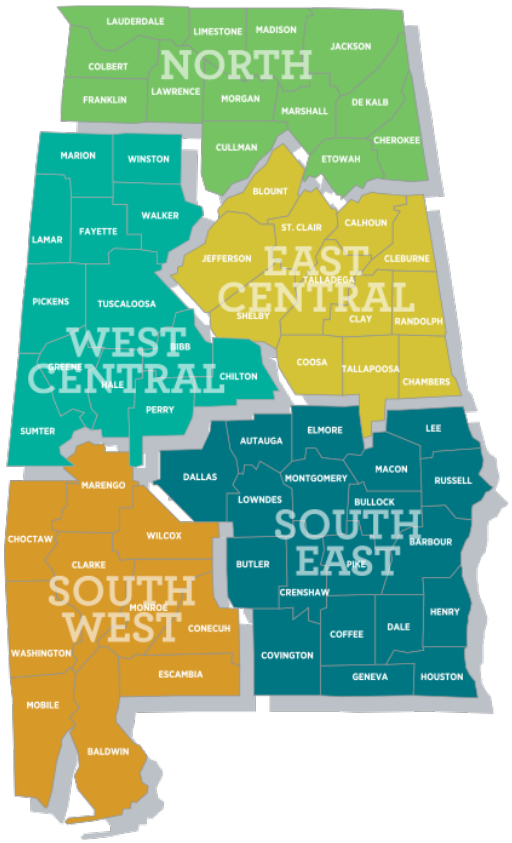


Figure 25. ALDOT Regions
Source: Alabama DOT

Herbicide treatments are an essential part of the ALDOT program as they reduce the number of costly mowing cycles, maintain vegetation is areas not well suited for mowing, and help to slow the spread of invasive vegetation species. The Environmental Protection Agency (EPA) has regulations that require DOTs to document types and amounts of herbicide used in treatment. This was a hand-measured reporting process by ALDOT. While it helped to maintain compliance with EPA regulations, it required a great amount of time by field staff. Time spent on hand-written reports by operators could range between 30 and 90 minutes for each trip made by the vehicles for treatment. Information from these field reports also needed to be entered by manually into a state Maintenance and Management System (MMS), which can create additional opportunities for human error in the data reporting process. ALDOT desired to improve the documentation process through automating the process of environmental reporting by operators of those vehicles.

4.6.2 ALDOT System Procurement

ALDOT staff involved with herbicide treatments were familiar with a local agricultural equipment distributor named Vantage South, which specializes in precision agriculture through the use of AVL/GPS technologies. ALDOT staff engaged in discussions with them on how an AVL system offered through Vantage South could meet their agency needs with reducing excessive herbicide treatments and improving the documentation process. In addition, ALDOT reviewed a number of other AVL system vendors that offered similar types of systems as the Trimble AVL system that Vantage South offered. Those systems utilized hand-held tablets that operated with mobile applications, which would have required system testing by ALDOT to verify compatibility with existing ALDOT systems and software. The AVL system manufactured by Trimble, on the other hand, had the potential to electronically document herbicide treatments and maintain files, which would reduce not only the cost of manual efforts, but also the potential for human error by vehicle operators in entering information by hand during vehicle shifts.

In addition, Vantage South had independently developed a data delivery system to meet the needs of large scale agencies, such as ALDOT, that wanted to integrate data from Geographic Information System (GIS) software with an on-board AVL system to present critical information to vehicle operators making herbicide treatments. All other vendors would have required data to be delivered into their proprietary systems, and then manually exported by ALDOT staff into a non-proprietary format for use with GIS software.

Given this review, ALDOT procured the Trimble AVL system through a sole source procurement for a pilot project. ALDOT also required that Trimble integrated the AVL/GPS system with in-vehicle equipment on herbicide spray vehicles to allow for automated environmental reporting.

Separately, ALDOT used the existing state contract with Southern Linc to purchase AVL/GPS hardware known as Comet Tracker manufactured by ActSoft for other vehicles (light-weight, maintenance vehicles and trucks) statewide.

4.6.3 ALDOT System Implementation and Integration

ALDOT has two separate AVL/GPS systems implemented on their vehicle fleets that are used for different agency purposes. These are described below:

- Trimble – The Trimble AVL System is used with herbicide spray vehicles on a statewide basis. Tablet devices are hard-wired and mounted in the vehicle and connected with spray equipment to manage treatment amounts applied along roadway segments. Central software used for monitoring vehicle locations, understanding what areas have been treated, and gathering vehicle data during or at the end of a vehicle shift. Still working with vendor on reporting additional information such as targeted plants and type of herbicide used.
- Comet Tracker – Comet Tracker devices are used with other vehicle types (light-weight vehicles, maintenance vehicles/trucks) on a statewide basis. Small hardware device is connected with on-board diagnostic port of the vehicle. Central software used by agency staff for monitoring only the vehicles applicable to their department.

The Trimble vehicle hardware device used with ALDOT herbicide spray vehicles is displayed in Figure 26. The tablet devices have a cable interface with an on-board device that can control the operation of spreader and spray equipment. This allows an operator in the passenger seat of the vehicle to monitor the amount of herbicide application being applied, and to make adjustments as needed during treatment. Figure 27 displays screens that are viewable to operators of herbicide spray vehicles. This provides information to the operator on the targeted amount of herbicide to use in treatment operations. Additional screens can present to operators specific areas to be avoided with herbicide treatment as well.

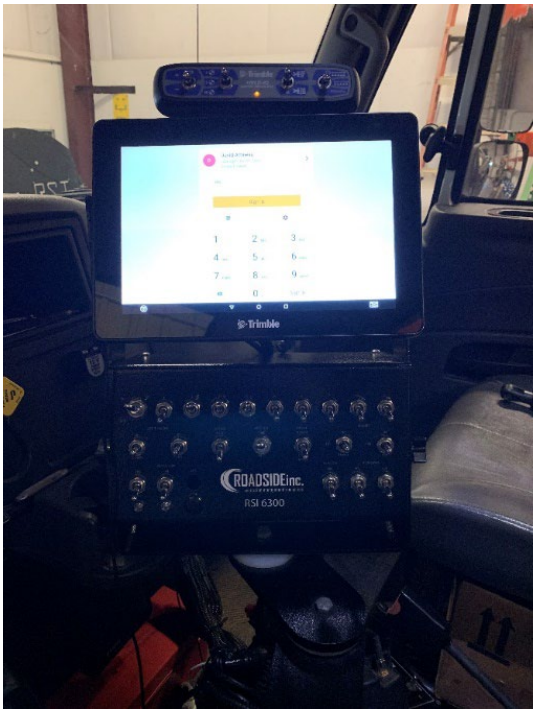


Figure 26. ALDOT In-Vehicle Trimble AVL System Hardware

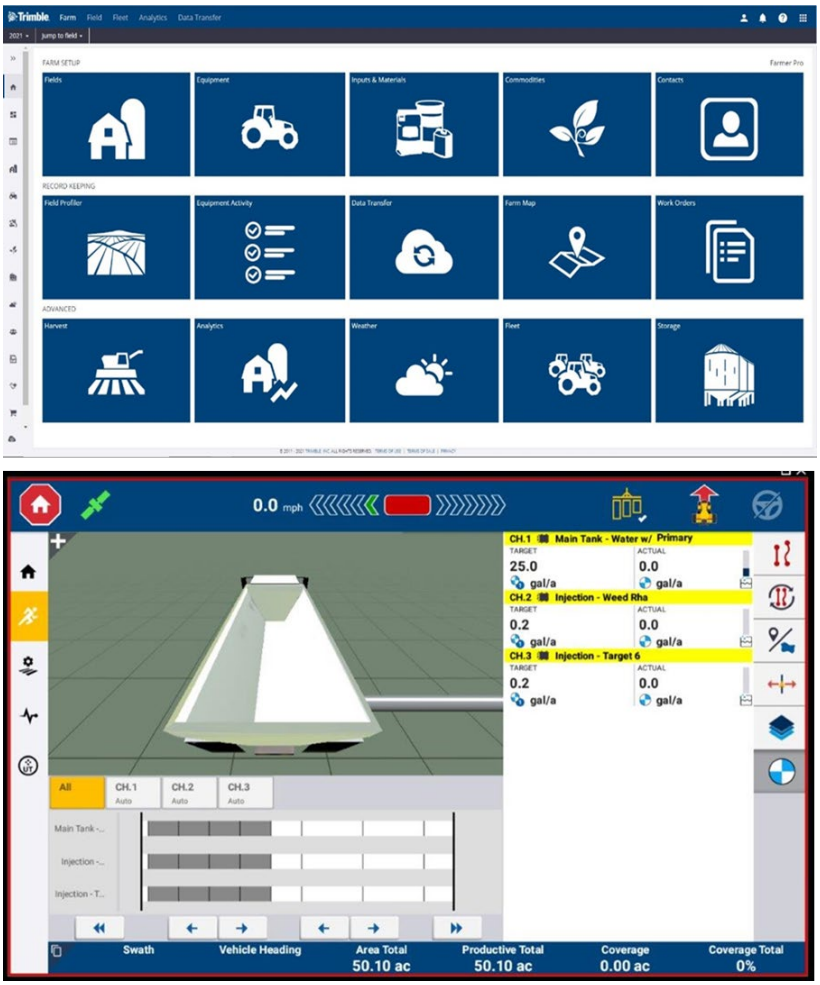


Figure 27. Trimble Home Screen and Run Screen

The installation of the Trimble AVL system and its integration with other on-board equipment was performed by the dealer that provides herbicide spray vehicles. For the Comet Tracker AVL system, ALDOT vehicle yard management staff perform the basic installation of the hardware with the on-board diagnostic ports of the vehicles.

Trimble devices can be connected to a wireless Mi-Fi mobile hotspot device on the herbicide spray vehicles for data reporting in near real-time. Vehicles can also upload their data at the end of their shift using the Wi-Fi capability of the mobile hotspot in the vehicle garage. Mi-Fi mobile hotspot devices are also provided from Vantage South.

Comet Tracker devices are primarily used for fleet management purposes on state vehicles. These devices use a cellular signal to transmit data on the vehicle location as well as vehicle mileage. The state of Alabama had entered into a contract with a regional cellular service provider, Southern Linc, to transmit data from the AVL/GPS systems to system data servers.

4.6.4 ALDOT System Software

The Trimble AVL system is compatible with ALDOT GIS software, which allows for additional information to be presented to operators during treatment operations in the field. This information logged within ALDOT GIS software graphically indicates areas to be avoided with herbicide treatments by the vehicle operator. This includes the following items:

- The locations of endangered species in the state
- Municipal Separate Storm Sewer System (MS4) outfalls. These are points where separate storm sewer systems discharge to surface waters or another MS4 area. MS4 outfalls include discharges from pipes, ditches, swales, and other points of concentrated flow.
- Other environmentally sensitive areas within the state.

The Comet Tracker central software is used by ALDOT for monitoring several types of maintenance vehicles, as shown Figure 28. The Comet Tracker system is administered by ALDOT's fleet management system. Specific departments can be given access to the system software to monitor the locations of vehicles that only apply to their department. The software is used internally by ALDOT staff only, and vehicle location information is not shared with the public or other external agencies.

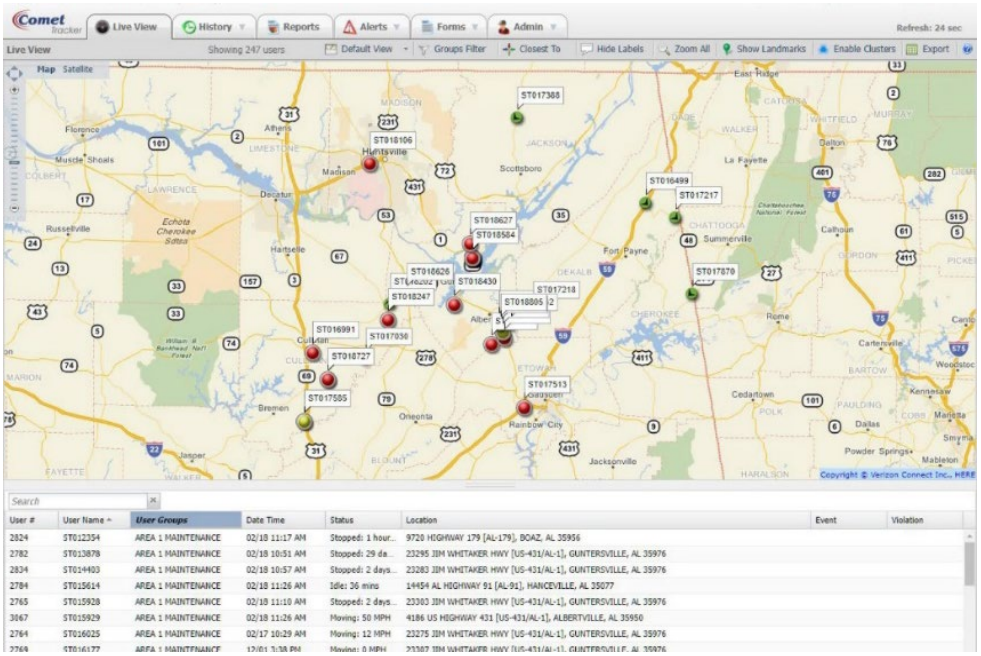


Figure 28. Screenshot of Comet Tracker Software Interface for Vehicle Tracking

ALDOT has integrated the Comet Tracker system with its ALGO Advanced Transportation Management System (ATMS) software. The ATMS software collects data, distributes traffic information, facilitates management of incidents through standard response plans, and provides full control over ITS field devices. Each ALDOT Alabama Service and Assistance Patrol (ASAP) vehicle is outfitted with Comet Tracker devices and transmits its location to the central management software. This integration allows for the traffic

management center operators to identify and dispatch the nearest available ASAP vehicle to an incident on the roadway.

4.6.5 ALDOT Data Collection and Utilization

A summary of the data collected by ALDOT on non-winter maintenance operations is presented in Table 17.

Table 17. Types of Non-Winter Maintenance Operations AVL/GPS Data Collected by ALDOT

AVL/GPS Data	Type of Non-Winter Maintenance Operations
Vehicle Location Data	Herbicide Spray Operations Vehicle Maintenance Operations
Herbicide Treatment Information for EPA Reporting	Herbicide Spray Operations
Vehicle Mileage	Vehicle Maintenance Operations
Vehicle Speed	ASAP Vehicle Operations

Trimble AVL/GPS devices are currently being used by ALDOT on herbicide spray vehicles to electronically collect information that can be stored automatically on operator reports. ALDOT noted that Trimble devices could also be used during disaster cleanup and recovery efforts to record how many cubic yards of area has been cleared. In addition, ALDOT is working to gather ground speeds of their vehicles through the Trimble device when those vehicles are used to treat roads during winter weather events.

ALDOT uses the Comet Tracker for the following operational purposes:

- Reports on vehicle mileage that exceed certain thresholds. Different types of vehicle maintenance can be automatically scheduled, which can reduce the amount of paper reporting by supervisors, help to extend a vehicle's use life, and allow for improved fleet management.
- Geo-fences can be set up through the software to define areas in which the vehicle should remain, and alerts can be created if the vehicle travels outside of the geo-fences.
- Supervisors can indicate on the state's 511 website on which roads have been treated during occasional winter weather events. This helps to inform the public on which roads are safe to travel during those types of events.

4.6.6 ALDOT System Benefits and Costs

A summary of the AVL/GPS hardware and installation costs provided to ALDOT in 2021 are provided in Table 18.

Table 18. Hardware, Installation, and Fees of ALDOT Trimble AVL/GPS System

Items	Quantity	Unit Cost	Total Cost
System Hardware Items			
Trimble Basic GFX-750 Display and Nav-900-DGPS	1	$4,564.43	$4,564.43
Field-IQ Spray Control System – Generic Signal Input Module Kit (Power Bus Req)	1	$771.40	$771.40
Master Switch Box Field-IQ with Mount Kit	1	$360.33	$360.33
Field-IQ Spray Control System - with Full Harness	3	$1,766.10	$5,298.30
Electric Pump Driver for 12 Volt Pumps, PWM	2	$500.00	$1,000.00
Cable Kit, GFX/XCN-1050, Full Harness, ISOBUS	1	$908.43	$908.43
Cable Assembly, GFX/750/XCN-1050, Field IQ-Active CAN terminator	1	$172.55	$172.55
Raven Control Valve	1	$340.00	$340.00
Cable Assembly, Field-IQ TO Raven Fast Valve (New Style)	1	$93.38	$93.38
License, Display-Multi Type, Implement: ISOBUS Multi-Product	1	$532.88	$532.88
System Installation Items			
Installation Labor	1	$1,000.00	$1,000.00
Annual Fee - Farmer Pro	1	$1,814.82	$1,814.82
Annual Fee - Display Connection (Office Sync + Fleet)	1	$100.49	$100.49
Total System Cost			**$16,957.01**

ALDOT has noted that they have been very well commended for how the system has been used for state operations. This process of automated reporting helps reduce the chances of human error in operational reporting while allows more time to operators to focus on safely and efficiently performing herbicide spray treatments. Currently, both hand reporting and electronic reporting are being done, though once the integration with MMS is complete, it is envisioned that the process of reporting for EPA compliance will be automated.

Another benefit observed by ALDOT is that supervisors can use the software to visually view which areas of roadside vegetation have been treated. This information can be used to assist with reporting and providing a visual representation for operators to determine what areas still require treatment.

In addition, the systems have help exonerate vehicle operators from property damage claims by the public. Central software reports can identify the location of state vehicles at specific locations and times, which can be provided to motorists that may claim an ALDOT vehicle was responsible for damage to their vehicles.

4.6.7 ALDOT Issues and Challenges

Institutional Issues

Vehicle operators have not expressed "big brother" types of concerns with either the use of the Trimble or the Comet Tracker system.

Technological Issues

ALDOT has found that there have been very few issues with the operation of the Trimble system. The only known issue was related to a software upgrade that ALDOT staff adjusted to by altering the use of the system. Calibration of the Trimble hardware on herbicide spray vehicle is done at the start of every shift to ensure accurate usage of herbicide spray by the vehicle during its operation.

4.6.8 ALDOT AVL/GPS Lessons Learned

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

- ALDOT has found that their request for automated reporting related to herbicide spray operations helps to expand the horizon of the equipment vendor (Vantage South) which typically works in agricultural settings. This can help to advance the industry in supporting other DOTs that may be looking for similar systems.
- Automating the process of environmental reporting as part of herbicide spray operations is anticipated to save the agency staff time and resources and to improve the accuracy of data entered in the field by operators over the long term.

5. Additional Information from Other Agencies

In addition to the five case studies, three other agencies were interviewed to help gather information to supplement the observations and findings from the case studies. The three agencies are: New Hampshire DOT (NHDOT), Massachusetts DOT (MassDOT) and Colorado DOT (CDOT). One of the particular interests of this project is to gather information and experience from agencies that transfer AVL/GPS systems between winter and non-winter maintenance vehicles/equipment. Based on the survey responses and literature research, very few agencies are performing such transfers. NHDOT and MassDOT are two of the few agencies transfer AVL/GPS units between winter and non-winter maintenance vehicles.

Information gather from the three agencies are summarized below.

5.1 New Hampshire DOT

NHDOT has implemented an AVL/GPS system on their agency's fleet of winter and non-winter maintenance vehicles from Skyhawk Technology Systems (STS). NHDOT currently has 89 STS AVL/GPS units on winter maintenance vehicles, and six of these units are installed on snow plow vehicles that also spread material to treat the roadways. These six units are transferred to other vehicles such as street sweepers and roadside mowers in the non-winter months. NHDOT's main reason to transfer AVL/GPS units between vehicles is to justify the investment, as many of the units are installed on winter maintenance vehicles and

used only during winter months. Although STS offers a reduced data usage plan for non-winter months of the year, NHDOT desires to increase the usage of the AVL/GPS system all year round.

5.1.1 NHDOT System Implementation and Unit Transfers

To transfer or relocate AVL/GPS units from winter maintenance vehicles to non-winter maintenance vehicles, NHDOT first needed permission from STS. Once STS granted permission, NHDOT first worked with street sweepers and had a trial-and-error period with use of the AVL/GPS equipment on those vehicles. Once NHDOT fine-tuned and was satisfied with the installation, the process of moving the equipment back and forth between vehicles became straightforward and took about 10 minutes to perform the movement and installation into another maintenance vehicle. Settings that were created for each different vehicle stayed with the unit that was transferred between vehicles. Movements and installations of the AVL/GPS units are performed by NHDOT staff, and remote support is provided by STS in the event of issues with operations.

On roadside mowers, AVL/GPS units are only integrated with the power-take-off (PTO) link. The agency needed to assess how much area was mowed by the vehicle given that mowers would often go back and forth to complete one area, which would be measured by GPS as a much smaller area than what was actually mowed. The agency used the amount of time that the mower was turned on from the PTO link and measured the width of the mower to calculate an estimated amount of square footage that was mowed by the vehicle.

On street sweeper vehicles, AVL/GPS equipment is integrated with the left/right/center switches on the sweeper vehicles. GPS equipment indicates the areas in which the vehicles operated, and this allows for an understanding on where the vehicles were active for street sweeping.

NHDOT also noted that not much calibration was needed for integrating on-board equipment with the AVL/GPS unit.

5.1.2 NHDOT AVL/GPS System Data Collection

NHDOT indicated that data gathered from the AVL/GPS system for non-winter maintenance activities is primarily used in tort claims where the system helps demonstrate the location of vehicles during a reported incident.

NHDOT would desire to have engine hours and mileage data collected from the vehicles by the AVL/GPS system equipment. This would support their maintenance of vehicles when vehicle diagnostic codes are displayed but not seen for a period of time. They would be able to go back and determine how many miles were driven when the vehicle needed to have maintenance performed.

NHDOT vehicles with the AVL/GPS equipment have the capability to send text messages or email alerts to supervisors when vehicles are measured as traveling faster than 4 miles per hour over the posted speed limit for specific roadways. This can be used to communicate concerns from supervisors to the vehicle operators where needed.

STS sends all raw AVL data to its customers and allows them to develop their own customized reports to support maintenance operations. While the data can be overwhelming, NHDOT felt that it provides flexibility and cost efficiency for reporting on maintenance operations.

5.1.3 NHDOT Observations and Lessons Learned

NHDOT noted that potential reasons for why other agencies may not be as willing to move AVL/GPS equipment between vehicles may be that system vendors simply do not allow the agency to perform the transfer process. There may be contractual provisions that prevent or discourage agency staff from moving the equipment to non-winter maintenance vehicles during non-winter months. This may include voiding of any equipment warranties or additional fees to the agency for training on how to configure the equipment during the transfer process. Some agencies may have larger fleets that have the AVL/GPS equipment integrated with other in-vehicle systems, and the process for documenting the transfer of equipment may be too burdensome for the agencies.

NHDOT has not fully utilized all of the capabilities of its AVL/GPS system, mainly because they have not had the staffing resources to fully test all of the requirements that were placed on the system when it was procured. A general lesson learned for agencies when utilizing these systems for the first time is to take small steps with using data from the AVL/GPS system to support specific types of operations, and gradually take on more of the system as staff and other resources allow over time.

NHDOT is looking to come out with an RFP soon for AVL/GPS system for their vehicle fleet. Based on the experience with testing of the STS equipment and discussions with other system vendors, the following general observations are offered to help guide other agencies looking to procure AVL/GPS systems for fleet operations:

- NHDOT has met with several system vendors to understand their current capabilities, and would like to see an AVL/GPS system demonstrate all of the agency's desired features to prove that it is capable from the outset of the installation. Many vendors not capable of certain features may claim "we can develop it" for a future hardware/software update. However, such claim may turn into a black hole in which the desired functions may never come to fruition, or that additional fees may be requested for its implementation.
- Agencies that utilize low-bid processes for procuring an AVL/GPS system may run into issues later on with use of the system capabilities, or the ability to retain system data for historical use. It is critical to structure system requirements with low-bid procurement in a manner that they will provide the agency the desired functions and capabilities for operational use.
- It is very important for agencies that desire to use the AVL/GPS system for operational reporting to require that the agency be able to claim ownership of all the system data. The vendor may be able to store all of the data for the agency, but ideally the agency should have the ability to recover the data at a later date in the event of tort claims and environmental issues.

5.2 Massachusetts DOT

MassDOT utilizes an AVL/GPS system for winter maintenance operations and provides the AVL/GPS equipment to private contractors that perform about 90% of winter maintenance activity for MassDOT. AVL/GPS equipment is placed only on vehicles with salt spreader equipment that treat roadways with granular salt or liquid brine based on weather conditions. The AVL/GPS equipment was integrated with spreader controllers on about 75 vehicles operating in environmentally sensitive areas.

A primary use of the AVL/GPS system is to allow MassDOT for tracking contractor vehicles and verifying routes have been treated, since private contractors execute most of MassDOT's snow mitigation. The AVL/GPS equipment only collects telemetry data on contractor vehicles. The telemetry data includes vehicle locations and vehicle speeds. The data can be reviewed during winter operations to remind vehicle operators to maintain a speed between 25 and 30 miles per hour while spreading salt material during winter weather events. The data gathered from the AVL/GPS system equipment may be used in tort claims where needed to demonstrate the location of vehicles during a reported incident.

The state also contracts 34 non-agency vehicles for Highway Assistance Patrols (HAPs), and the inclusion of GPS devices with these vehicles ensures that MassDOT's Highway Operations Center (HOC) can route the nearest HAP to a motorist reported in need of assistance.

MassDOT District 5 staff were involved in the transfer of the AVL/GPS equipment between winter and non-winter maintenance vehicles to track other essential roadside maintenance activities, such as mowing and litter collection. There were nine AVL/GPS devices that were transferred from winter maintenance vehicles by MassDOT's District staff to non-winter maintenance vehicles. The process of transferring the AVL/GPS devices between vehicles was simple and involved unplugging the AVL/GPS device from the cigarette lighter 12-volt power supply and then re-plugging it into another vehicle. However, the AVL/GPS devices on those vehicles were used to collect telemetry data only. As such, the AVL/GPS device transfer and installation process did not require integration with other in-vehicle equipment.

MassDOT has recently entered into an agreement with Geotab as a new AVL/GPS provider. Approximately 1,300 contractor vehicles will be outfitted with the Geotab devices by late 2022. MassDOT is currently identifying which contractor vehicles will receive spreader-integrated setups. Under the new agreement, Geotab will provide the telemetry data for future system operations on both contractor vehicles and MassDOT vehicles. Equipment will be installed on contractor vehicles and MassDOT vehicles in a manner that does not allow for easy removal of the devices by vehicle operators.

MassDOT will discuss with other state districts to see if they see any value in moving the newer Geotab AVL devices between winter and non-winter maintenance vehicles operated in those districts.

5.3 Colorado DOT

CDOT has implemented an AVL/GPS system from Geotab (GO9 system) on their fleet of winter and non-winter maintenance vehicles. CDOT procured the Geotab system for all fleet vehicles to replace their prior AVL system from Zonar and Verizon. CDOT's main focus with the AVL/GPS system was improving situational awareness for both winter maintenance and non-winter maintenance vehicles and equipment.

Situational awareness refers to knowing where agency assets (vehicles and equipment) are located at any given time for all types of maintenance activities.

CDOT utilized specifications developed by the California Department of Transportation as a starting point and added system specifications CDOT specifically desired. CDOT also gathered information from multiple vendors to help the development of the specifications.

The Geotab system was first implemented on high-priority vehicles (snow plows, tandem vehicles, etc.), followed by other vehicles in the fleet. Location trackers, referred to as "GO9 Rugged" also from Geotab, were installed on other mobile assets such as portable dynamic message signs (DMS), mowers and other non-winter maintenance vehicles. CDOT does not move their AVL/GPS system equipment from one vehicle/equipment to another.

CDOT courtesy patrol vehicles are also equipped with tablet devices that allow vehicle operators to enter data on traffic incidents along the roadways. This is part of a CDOT Incident Clear program that helps to gather data and communicate incidents impacting traffic conditions to the general public. All contractor operated vehicles for the state are also required to have AVL equipment installed on them to assist with vehicle location and data reporting.

The system vendor performed the initial installation. CDOT maintenance staff were also trained on how to installed the system. Overall, the installation is straightforward and easier than the previous systems, and the AVL/GPS system has not required much in terms of equipment maintenance or replacements.

CDOT has developed a data hub that is used internally to collect AVL/GPS system data and distribute it to various applications. CDOT's data usage with the AVL/GPS system are described below:

- CDOT has developed a mobile phone application to help vehicle operators to meet pre-trip and post-trip reporting requirements for heavy duty vehicles used for winter and non-winter maintenance operations. This use of mobile phones has replaced the use of tablets for the prior system provided by Zonar. Pre-trip and post-trip reports are sent from mobile phones to a storage area within the data hub.
- TMC operators can use AVL data to support traffic incident management. TMC operators use the data for locations of courtesy patrol vehicles and maintenance supervisor vehicles, allowing timely response to incidents and traffic control/maintenance asset requests.
- CDOT has used AVL/GPS historical data on vehicle locations to address tort claims of damage to private property.
- CDOT has been able to locate equipment that has been moved around on them during non-winter maintenance events, namely summer fires. This equipment has included DMS trailers, water trailers, and other heavy equipment to support fire prevention.
- CDOT has been using the AVL/GPS system to document fuel usage and mileage by all fleet vehicles over time to better understand how fleet utilization. This data helps to justify uses of differing amounts of operational resources by different maintenance groups as well as the investment on its fleet.

- The AVL/GPS system also supports CDOT's green initiative. System data is used to track fuel usage and assist in budget planning.
- CDOT also uses the AVL/GPS system to support process automation and paperwork reduction. As an example, the data allows CDOT for matching fuel usage with fuel receipt which effectively reduces frauds in fuel purchases.
- CDOT uses the AVL/GPS system to monitor driver behavior. Alerts are generated for vehicles traveling at speeds above a certain threshold.
- The AVL/GPS system data is used to support budget and planning for the maintenance program as a whole.
- CDOT has also been able to use the AVL/GPS system to recover stolen vehicles through use of the AVL/GPS system software.
- CDOT heavy duty maintenance vehicle locations are shared with the general public through a COTrip.org traveler information website.

CDOT noted that the ability to use the system for recovery of stolen vehicles and equipment provides great benefits. The savings from this probably exceed the cost of the system. It was also noted that the state of Colorado has recently issued a requirement for all state agency vehicles to be equipped with AVL/GPS system equipment.

6. Conclusions and Recommendations

This section summarizes the key findings and offers conclusions from this study. It also provides lessons learned from the case studies as well as recommendations to help highway maintenance agencies make more informed decisions with respect to the implementation of AVL/GPS technology for all year round maintenance activities.

6.1 Findings and Conclusions

- Few agencies transfer AVL/GPS system equipment between winter and non-winter maintenance vehicles. 31 of the 52 agencies that responded to the survey have AVL/GPS systems on both winter and non-winter maintenance vehicles. NHDOT and MassDOT are the only agencies that currently moving their AVL/GPS system equipment between winter and non-winter maintenance vehicles. The majority of the agencies interviewed have implemented AVL/GPS technology to their entire maintenance fleet.

- NHDOT and MassDOT perform transfers of AVL/GPS equipment between winter and non-winter vehicles. NHDOT currently utilize an AVL/GPS system provided by Skyhawk. MassDOT was using AT&T Fleet Tracker and is transitioning to Geotab AVL/GPS system. Both agencies utilize agency staff to perform the equipment transfer, and both indicates the transfer/installation processes are straightforward. In the case of MassDOT, the process involves unplugging and re-plugging power supplies between vehicles, as the AVL/GPS devices are used to collect telemetry data only without additional integration with other in-vehicle equipment. In the case of NHDOT, the AVL/GPS devices are integrated with the PTO (power-take-off) links on mowers and the left/right/center switches on sweepers. The transfer and installation process for NHDOT takes about 10 minutes to

complete. Both agencies noted that calibration of the AVL/GPS equipment upon transfers is minimum, if any.

- All five case study agencies implemented AVL/GPS systems on their entire fleets. Four of those agencies perform both winter and non-winter maintenance activities. All four agencies utilize their maintenance vehicles on a year-round basis. That is, maintenance vehicles that are used as snowplows during winter months are also used during non-winter months to perform other highway maintenance activities such as roadway paving, seal coat operations and paint striping.

- AVL/GPS systems have been integrated with a variety of in-vehicle equipment and other systems for non-winter highway maintenance operations, including:
    - Hydraulic system switches/broom position sensors on sweepers
    - Sprayer controllers on herbicide spray vehicles
    - PTO links on mowers
    - Dashcams
    - Roadside dynamic message signs notifying drivers that crews are working in immediate downstream
    - GIS software

  Integration of AVL/GPS systems with many of the in-vehicle devices can be accomplished through utilizing the OBD-II ports on vehicles.

- Common uses of the AVL/GPS system data for non-winter maintenance operations include:
    - Tort claims
    - Operator safety
    - Operator behavior/speed/seat belt usage monitoring
    - Asset/vehicle location tracking
    - Engine diagnostics
    - Maintenance operations planning
    - Vehicle utilization records such as hours and mileage of operations
    - Task-based maintenance activity monitoring, such as:
        - Miles of sweeping operations completed
        - Acreage of herbicide treatment
        - Striping on/off and amount of paint used
        - Acreage of mowing completed
    - Recovery of stolen vehicles and equipment

- Many agencies noted that they have not fully utilized all the capabilities of the AVL/GPS systems. The reasons include:
    - Agencies don't have the staffing resources to fully test of the functions and requirements of the systems.
    - Agencies currently don't have needs for the other features they are not using. For example, West Des Moines is aware that their system is capable of tracking paint and

herbicide usage data, but they don't have immediate needs in those areas due to the size of their operations.
    - The systems were implemented recently, and agencies don't have enough experience with the new systems or want to focus on the primary features they desired at the current time.

- Key benefits with using AVL/GPS systems for non-winter highway maintenance operations observed from the case studies are summarized below.
    - Improving operator safety. This is a primary goal of using AVL/GPS systems for many agencies included in the case studies. AVL/GPS systems allow agencies to observe if a vehicle is stopped at one location for an extended period of time, which may indicate potential issues related to the vehicle or the operator. Agencies can use the systems to check on the safety, security and well-being of the operators and vehicles. Agencies can use the location data to respond to situations quickly.
    - Promoting speed compliance and seat belt usage. AVL/GPS systems can be used to monitor/verify vehicle speeds and seat belt usage. This helps reduce the potential for injury and keep maintenance and liability costs low. MoDOT has observed an 85% increase in seat belt usage and a 70% decrease in speeding events over the first year of their system usage on a statewide basis.
    - Reduction of liability and tort claims from the general public is another key benefit that can be realized by utilizing AVL/GPS systems for non-winter maintenance operations. In addition to reduction in public agencies' liability, this helps vehicle operators recognize that the system is a valuable tool to protect them as well as promote their acceptance of the system.
    - Reporting automation. Automation of data processing and report generation helps improve data accuracy, reduce the chances of human error in operational reporting, save staff time and resources, and allow more time to operators to focus on safely and efficiently performing their duties.
    - Improving vehicle maintenance. When AVL/GPS systems are connected to the vehicle OBD-II port, engine diagnostic data can be obtained and transmitted to the central software for review by maintenance supersivors or technicians. AVL/GPS system software can single out serious engine diagnostic alerts and send an automated email directly to supervisors about the issue.

6.2 Lessons Learned and Recommendations

Lessons learned and recommendations from the case studies are offered below.

- Communication with field operators and maintenance supervisors regarding the value of the system is critical. Field operators may feel that AVL/GPS systems are a "big brother" watching every move they make and another mechanism to catch them doing something wrong. Developing a clear communication message on what the AVL/GPS system is and how the system will be used can help both supervisors and operators increase the safety of maintenance operations, and over time, increase the benefit to the department in terms of tort claims, resource usage, and other areas.

- Providing vehicle operators access to the system helps them to realize the benefits and minimize the "big brother" syndrome. Educating staff about how the information gathered by the system will be used is also important.

- Agencies interested in AVL/GPS procurement are encouraged to do their homework first on what they need from the system. Equally important is that homework should be done on AVL/GPS systems that agencies are interested in procuring to understand the main features and capabilities of those systems.

- Reviewing agency needs with respect to winter and non-winter maintenance operations can lead to better defined system specifications and a scope of work. Obtaining information and lessons learned on how other peer agencies have implemented systems to improve their winter and non-winter maintenance operations allows for gathering additional ideas on how to improve upon their own operations.

- Deciding upfront what data to collect and utilize for the agency helps to set expectations. However, it is important to recognize that too much data could create overload on maintenance supervisors.

- It is important and beneficial for agencies to work closely with the AVL/GPS vendors on any customized reports that agencies desire to have developed. It is also important for agencies to verify the data within those reports to make sure the system is pulling it correctly.

- Agencies' requests for automated reporting and customized reports can help expand the horizon of AVL/GPS system vendors. This can help to advance the industry in supporting highway maintenance agencies to perform more effectively and efficiently.

- A plug-and-play type of system through use of the OBD-II port and the T-harness to connect with in-vehicle equipment offers flexibility for installation and integration.

- Having a champion to manage the program is critical. There will be technical, software, integration and other issues. It is important to have someone knowledgeable and proactive in working toward alleviating issues.

- Agencies should consider starting the deployment of the AVL/GPS system as a pilot project to demonstrate new uses of the system within a smaller area (such as a DOT district). It is critical to perform a pilot where there is "buy-in" and support in place for the project. As the concept is proven, agencies can expand the system to other areas. In addition, agencies can encourage staff to propose new use cases and applications of the AVL/GPS system. This is beneficial for agencies in determining use cases for the AVL/GPS system to support different types of non-winter maintenance activities.

Appendix A – Highway Maintenance Agency Survey Responses

Available separately; contact the Clear Roads administrative contact (see https://clearroads.org/contact-us/) for access.

Appendix B – Case Study Interview Summary: Missouri DOT

Overview

Virtual interviews were conducted by Mallory Crow and Dan Nelson of AECOM and coordinated with the assistance of Paul Denkler with the Missouri Department of Transportation (MoDOT) on Mon. Feb. 7th and Mon. Feb. 14th, 2022.

MoDOT Staff Interviews

Meeting attendees on Mon. Feb. 7th included the following individuals:

- *Paul Denkler, MoDOT Maintenance Liaison*
- *Natalie Roark, PE, State Maintenance Director*

Meeting attendees on Mon. Feb. 14th included the following individuals:

- *Paul Denkler, MoDOT Maintenance Liaison*
- *Tim Bundgard, Maintenance Superintendent, SW District*
- *Sheldon L. Redel, Senior Procurement Agent, Central District*
- *Kyle W. Fischer, Senior Maintenance Operations Specialists, Central Office*
- *Rodney Joseph Colbert, Equipment Technician Supervisor, Central District*
- *Aaron Underwood, General Services Manager, SW District*
- *Mike Belt, Maintenance Superintendent, Central District*

MoDOT Executive Level Interview – Feb. 7th

MoDOT has implemented an AVL/GPS system from Geotab on their agency's fleet of winter and non-winter maintenance vehicles which includes the following equipment:

- GO9 vehicle hardware includes a small device that connects with any vehicle's On-Board Diagnostics (OBD) port for integration with other on-board vehicle systems, such as spreader controller or plow/broom sensor on the vehicle. The GO9 device also uses cellular technology to communicate data from the vehicles to a web server that is managed by Geotab.
- A web-based user interface is utilized by MoDOT staff to view data on vehicle locations in real-time and can also be used to generate different types of reports on maintenance operations.

MoDOT staff noted that while the system was initially installed for its engine diagnostics capabilities in a few districts in 2015, a driving factor for later implementing the system statewide was the improvement in driving safety that could be achieved through use of the system.

AVL/GPS System Procurements

Three MoDOT districts (Southwest, Central, and St. Louis) initially began with a pilot of the AVL/GPS system from Geotab in 2015. The districts initially wanted to test an AVL/GPS system for engine diagnostics features to determine when check engine lights were activated and measure vehicle mileage among other items. Each of the 3 districts individually managed its procurement through a solicitation process for the AVL/GPS technology, and each district selected Geotab as its AVL/GPS vendor.

MoDOT staff noted that with the different procurements, there were different equipment distributors for Geotab in those districts. Over time, each district also added different features of Geotab to their maintenance operations, which made it difficult to monitor and compare how the AVL/GPS was being used. With the different procurements, there were also different "silos" in which AVL/GPS information was stored for each district, which also made it difficult to evaluate the benefits of using the system in those districts.

In 2018, MoDOT developed an AVL/GPS team to consolidate data from these silos into a central source of data and to begin planning for an expansion of the system statewide. As a first step, MoDOT utilized Sourcewell as a procurement process to select one equipment distributor for all three MoDOT districts involved in the initial pilot. This also allowed for MoDOT to consolidate the data and information from the districts into a central location for better understanding how the system was used in all three districts. This in-house central data source for MoDOT is referred to as the Maintenance Management System (MMS).

As a second step in the procurement for a statewide expansion, MoDOT coordinated with the California Department of Transportation (Caltrans) to review a procurement specification that was used by Caltrans to eventually select Geotab as a vendor for their AVL/GPS system. Caltrans developed the specification to be open for use by other state DOTs, and MoDOT adopted the specification for use in its procurement of Geotab devices statewide in Missouri. In addition, cities and counties within Missouri can also use the MoDOT contract to purchase Geotab devices for their public works fleets if desired. MoDOT works with a single equipment distributor for its equipment as well.

AVL/GPS System Field Usage

MoDOT staff noted that Geotab equipment is installed in the following types of fleet vehicles:

- About 1,500 heavy-duty vehicles that are used as snow plows in winter periods and for other uses in non-winter periods. The MoDOT central office provided funding to support the procurement of Geotab equipment for these vehicles in all districts of the state. Currently, this fleet is about 92% equipped with the AVL/GPS technology from Geotab.
- Medium-duty and light-duty (passenger) vehicles. Each MoDOT district was given the option to procure Geotab equipment for its own fleet of medium and light duty vehicles, though funding was required from each district to complete the procurement and installation. Currently, the medium and light duty fleets are about 46% and 45%, respectively, equipped with the Geotab AVL/GPS equipment.

The system was tested by fleet supervisors in 2015 for engine diagnostics to monitor for check engine lights when activated, vehicle mileage, and vehicle idling hours to improve upon overall fuel efficiency. As additional features from Geotab were added over time by the first three state districts, MoDOT central office staff saw the value in expanding the system to all other districts for the purposes of increasing driver safety through coaching by district maintenance supervisors.

GO9 equipment is capable of monitoring seat belt usage and reporting on vehicle speeds that exceed a pre-determined threshold for a period of time. Daily reports are generated if seat belts are not utilized by an operator, or if a vehicle speed is either detected at 6 MPH over the speed limit for 3 minutes of time, or at 15 MPH over the speed limit for one minute of time. Supervisors can then check in with vehicle operators to discuss the report and communicate the value of seat belt usage and a better adherence to the speed limit. MoDOT staff noted an 85% increase in seat belt usage and a 70% decrease in speeding events over the first year of usage on a statewide basis.

In 2022, MoDOT is planning to review how the use of the Geotab system has impacted the amount of incidents involving MoDOT vehicles and the financial benefits in terms of reduced claims paid as a result of the incidents. This will help to further validate the system's benefits to the agency. The system may also expand to fleet vehicles used by the Missouri Department of Conservation.

AVL/GPS Operational Usage

MoDOT staff utilize the AVL system for retrieving engine diagnostics from fleet vehicles and assessing whether or not vehicles are required to immediately travel to a repair shop for servicing. Geotab hardware can interface with heavy duty vehicles manufactured by Navistar and can receive real-time engine diagnostics through an OnCommand Connection enabled by Navistar. Supervisors that are using Geotab software can receive an alert about the diagnostic issue and quickly respond to the issue, instead of waiting for a separate report on engine diagnostics to be generated by Geotab software on a daily or weekly basis.

It was noted that other manufacturers of heavy duty vehicles do not provide the same type of linkage, so this is unique to only Navistar brand vehicles. MoDOT is also working on a similar effort to gather similar engine diagnostic information from light duty vehicles.

MoDOT is currently testing out a process through Geotab referred to as ScanAlert, which would single out serious engine diagnostic alerts and then send an automated email directly to supervisors about the issue. Initially, several emails about the same issue were sent to supervisors, but MoDOT was able to determine the problem with multiple emails. This allows for alerts to get to supervisors who may not be actively viewing the Geotab software when the alert is detected.

MoDOT staff noted that a policy was developed to describe how the AVL/GPS system was being used to encourage safe driving among vehicle operators and that it could be potentially used in a disciplinary manner if there were a repeated number of un-safe driving violations reported by the system. The policy is provided to vehicle operators and helps to increase their awareness of the system on the vehicles. While maintenance supervisors do not actively monitor specific vehicle locations, they can receive reports on un-safe driving behaviors related to seat belt usage and driving over the speed limit as noted earlier.

It was noted that some vehicle operators were concerned about the system being used in a more active disciplinary manner. However, the system has been used to exonerate some drivers from citizen complaints about property damage and has also been used to recover a few stolen vehicles from the fleet in recent years. This has reduced many of the “big brother” types of concerns in many cases.

MoDOT has also worked with Geotab to develop a Safety Dashboard report to encourage safe driving by each district. The dashboard can provide an overall safety score that is based on metrics such as speeding, harsh braking, backing up, seatbelt use, and other items. Presenting a safety dashboard for each district can improve the safety of their drivers as well as the traveling public around them. This safety report can be generated at different intervals (weekly, monthly, 3 months, 6 months) to allow for viewing of trends in overall safety behaviors by the operators.

The safety dashboard can also help to reduce vehicle maintenance cost by reducing the wear and tear on fleet vehicles over time. While MoDOT has had a mileage milestone for determining when to replace a vehicle, it was noted that they may be able to increase this milestone mileage amount based on the reduced amount of maintenance in future years.

Another safety feature that MoDOT has tested with Geotab is gathering data on G-force measures gathered from a vehicle accelerometer and lateral movements that are detected on the vehicle. This would allow for any emergency messages to be transmitted in case a vehicle overturns or is exhibiting un-safe driving behaviors on roadway curves.

After the G-force alerts were first implemented, MoDOT found that calibration of the accelerometer equipment would be needed to reduce excessive alerts being provided to supervisors. It was found that vehicles receiving loads at quarries would shake from side to side after receiving a load at the quarry. This was addressed through placing a geo-fence in the Geotab software around the quarry to prevent alerts while loading at the quarry. In other cases, rough conditions on roadways contributed to excessive alerts. MoDOT then performed additional testing on a closed test track used by the Missouri State Highway Patrol for officer training, where MoDOT collected data as the vehicle was driven around the track to understand the proper speed and lateral thresholds to set for determining alerts. This type of calibration has helped to improve the overall confidence of supervisors in reviewing G-force alerts that can indicate un-safe driving behaviors.

Additional calibration was also needed on vehicles for the seat belt reporting through the safety dashboard. At times, the lack of a passenger seat belt would be detected if any objects were placed on the passenger seat. Over time, the passenger seat belt detection was turned off. In other cases, the driver seat belt was not detecting accurately, which was addressed through a review of the seat belt sensors on the vehicles.

MoDOT is internally testing a "Citizen Insight" feature made available from Geotab that would display on a public facing webpage the progress made by snow plow vehicles or other maintenance vehicles on a specific route. MoDOT may integrate this feature with other state data as well to display additional information. MoDOT staff noted there is a separate "Route Completion" feature through Geotab that is for internal agency use only which provides more data on the routes completed by plow operators and other operators as well.

System Installation and Maintenance

MoDOT staff noted that the statewide contract that allowed for expansion to all districts came with a per-vehicle cost of $18.50 per vehicle per month for use of the Geotab GO9 system. This was a significant reduction from the previous price MoDOT was paying through the Sourcewell contract and the independent district contracts that were initially set up in 2015

MoDOT staff noted that the initial installation process of the GO9 Geotab equipment in the vehicle required more time and resources than many of the districts had available at the time. This was due to initially having to locate all of the vehicles and schedule them for the installation. MoDOT staff noted that the overall process takes about 30 to 45 minutes per vehicle for the vehicle harness and the Geotab hardware.

MoDOT Supervisor Level Interview – Feb. 14th

MoDOT utilizes their AVL/GPS system to support multiple types of non-winter maintenance operations as described below:

- Roadside mowing. This involves the use of a "protector" heavy-duty vehicle that follows on the roadway shoulder behind the mower. The protector vehicle has AVL equipment installed.
- Roadway paving. Heavy duty trucks with AVL equipment can be monitored for when they arrive at a quarry. Driver identity can also be monitored through the AVL system
- Seal coat operations are performed every other year. AVL system in the vehicles is used by supervisors to direct vehicles operators on the route they should follow when they finish seal coating a segment of roadway.
- Paint striper vehicles. The system is currently measuring only when paint sprayers are on or off.

MoDOT is planning to install Geotab AVL equipment on the following types of equipment in the coming year as a pilot installation:

Roadside mowers. An auxiliary port on the Geotab hardware will integrate with the mower to measure the number of acres that have been mowed, which will be used for reporting purposes.

- Chemical herbicide spray vehicles. An auxiliary port on the Geotab hardware will integrate with the sprayer to track the width of spraying and the total acreage that has been treated. In addition, Geotab will provide a speaker to be installed in the vehicle that can alert the operator to areas that should not be treated.
- Street sweeper vehicles. Similar to roadside mowers, Geotab will be used to measure miles of sweeping that has been completed.
- Paint striper vehicles. There are multiple types of additional data that could be gathered through Geotab, including when each individual nozzle is being used for spraying and the amount of paint used. An additional auxiliary cable with 4 additional ports would need to be connected to the existing auxiliary cable to gather this additional information.

MoDOT works closely with BlueArrow Telematics, which is the distributor of Geotab system hardware and software, to confirm how the auxiliary ports should be connected to vehicle inputs that gather data on maintenance operations. MoDOT will be reviewing the accuracy of the data that is gathered on different types of maintenance operations in the coming year prior to using the data to estimate potential cost savings that may be realized from use of the system.

MoDOT also works closely with BlueArrow on custom reports that can be generated by the central software. BlueArrow does provide technical staff that visit in person to vehicle garages to assist with equipment installations where needed, as well as to assist with viewing software reports.

MoDOT has developed an in-house Maintenance and Management System (MMS) which currently receives data from Geotab on performance measures such as miles of roadway that have been treated in winter weather and the number of hours that operators have logged during maintenance operations. The additional planned Geotab installations as a pilot projects will also report their data gathered into the MMS. An Application Programming Interface (API) has been developed by Geotab to allow for data gathered through the AVL system to be made available to the MMS, which retrieves the data for storage in the MMS.

MoDOT is currently testing a pilot project with 500 vehicles in which overhead warning lights activated on the vehicle can trigger an in-vehicle message to passenger vehicles approaching along the roadway. The vehicles include Truck Mounted Attenuators, emergency response trucks, and snow plow vehicles and the overhead warning lights on these vehicles are connected to an auxiliary port on the Geotab harness. When the lights are activated, Geotab central software can send an alert to a separate HAAS Alert Safety Cloud system. No additional hardware on the vehicles was to enable the integration.

This separate HAAS Alert system can in turn send a notice to passenger vehicles that are using the Waze app for in-vehicle navigation. Waze can send a message about the vehicle with warning lights ahead. In addition, the HAAS (Heedful Audio Alert System) Alert system can also send messages directly to vehicles manufactured by Chrysler/Jeep/Dodge/Ram after 2018 that have in-vehicle messaging capabilities. The in-vehicle messages are a recent development in 2021 made possible by HAAS Alert in partnership with a global automaker that oversees those vehicle brands.

MoDOT staff noted that they will be testing a public works module through Geotab in the coming months that will gather information from the vehicles and provide a separate report that would be independent of the MMS.

MoDOT staff noted that each of the seven districts are assigned a Geotab system administrator who is responsible for inputting vehicle data and categorizing them as passenger, medium duty, and heavy duty in the system. Inconsistent vehicle assignments made by the districts could reduce the accuracy of the safety scorecards that were created through Geotab. MoDOT had to develop guidance for system administrators on how to categorize vehicles so that the safety scorecards accurately reflected the safety measures reported there.

Other General System Observations

The following are additional observations noted by MoDOT staff:

1. Regarding the initial use of safety dashboards and other custom reports, MoDOT noted that it may have at first felt like information overload for maintenance superintendents and supervisors. Central office staff worked to communicate the value of the reports to the field office staff and worked to address any issues in the Geotab system reporting as noted.
2. MoDOT staff also noted that the AVL system has been very useful for recovering missing vehicles. The central software can quickly be used to determine the location of a vehicle that is expected to be in a certain location.
3. MoDOT staff noted that many of the pilot installations that are tested in either the Central District, Southwest District, or St. Louis district, prior to expanding the pilots to other districts if desired.
4. The Geotab unit in the vehicle had a tendency to be accidentally knocked out of place by vehicle operators, which would impact data reporting. In rare cases, it has been found that the Geotab unit was removed from the vehicle. A Watchdog report in the central software can be used to detect missing units or vehicles in the system for finding these vehicles and operators. To alleviate the issue, MoDOT staff installed the devices behind the vehicle dash with a harness where the device was effectively out of sight of the driver.

Appendix C – Case Study Interview Summary: City of West Des Moines

Overview

Virtual interview was conducted by Ming-Shiun Lee, Mallory Crow and Dan Nelson of AECOM and coordinated with Bret Hodne of the City of West Des Moines, IA on Jan. 26th, 2022.

West Des Moines Staff Interviews

Meeting attendees on Wed. Jan. 26th included the following individuals:

- *Bret Hodne, Public Services Director*
- *Jeff Sherman, Operations Supervisor, Traffic Safety*
- *Rian Rasmussen, Fleet Manager*

West Des Moines Executive/Supervisor/Manager Level Interviews – Jan. 26th

The City has been using AVL/GPS systems for the past 15 years and has worked with different vendors during that time. In 2021, the City procured and implemented a new AVL/GPS system from Geotab referred to as the "GO9" system for their vehicle fleet, which includes the following equipment:

- GO9 vehicle hardware includes a small device that connects with any vehicle's On-Board Diagnostics (OBD) port for integration with other on-board vehicle systems, such as spreader controller or plow/broom sensor on the vehicle. The GO9 device also uses cellular technology to communicate data from the vehicles to a web server that is managed by Geotab.
- A vehicle "T"-harness connects other on-board vehicle systems with the OBD port for integration with the GO9 system on City vehicles.
- There are 12 portable Geotab devices that the City provides to independent contractors that clear snow in various areas of the City.
- A web-based user interface is utilized by City staff to view data on vehicle locations in real-time and can also be used to generate different types of reports on maintenance operations.

The City has been very pleased with the overall operation of the system since its installation in 2021. While it has been operational for winter maintenance activities, the City has not had much experience using it for non-winter maintenance activities, though the system will be installed on the entire fleet of public works vehicles.

Prior to 2021, the City had installed an AVL/GPS system from a company named Webtech Wireless. The previous AVL/GPS system had required a greater amount of repairs and maintenance over time, and became less reliable in terms of interfacing with spreader controllers and other equipment on the vehicles.

Geotab GO9 AVL/GPS System Procurement

The City utilized a procurement process that was managed by Polk County to procure the Geotab system for its vehicle fleet. The County's procurement contract allowed for municipal agencies within the County to also purchase devices directly from Geotab as an approved vendor for use with their maintenance vehicle fleet. City of West Des Moines utilized the County procurement for their vehicle, though other cities within the County did not have the funding to purchase devices for their fleets.

One of the driving factors for the agency to utilize the AVL/GPS system for non-winter-maintenance purposes was to reduce liability and tort claims from the general public regarding their operations. The AVL system has been used to locate where public works vehicles were on specific days in response to complaints from citizens regarding damage that may have been caused by those vehicles. City staff

noted that some states place a greater liability on public works agencies than other states, which can be a good reason to justify the investment in an AVL/GPS system.

The City had also utilized a Polk County procurement back in 2005 for the selection of the Webtech AVL system. Specifications were written by the County to define precisely what was required and a scope of work was written for the AVL vendor to complete as part of system installation. The City noted that this task of defining specs for the AVL system helps to refine what the agency needs prior to procuring an AVL system, which was important for the City. The City was hoping other local agencies nearby would install the same systems via shared procurement which would allow for shared data between nearby agencies; however, they were the only agencies that invested.

Geotab GO9 AVL/GPS System Field Usage

The City uses the Geotab GO9 system on its fleet of public works vehicles, which includes front loaders, graders, sweeper vehicles, paint trucks, light duty trucks, and snow plow vehicles.

The GO9 vehicle hardware plugs into the OBD-II port on the vehicles which allows it to gather vehicle diagnostic and other information as desired by the City for each type of vehicle. For non-winter maintenance vehicles, vehicle location is the primary data collected. The use of a "T-harness" allows for integration of the GO9 unit with other vehicle systems. One example is understanding the "up/down" status of vehicle brooms on street sweeper vehicles. The central software can present what areas the vehicle has traveled with its brooms in a "down" state, which helps the City assess what areas have been treated over time.

The City is aware of other features from Geotab that would allow them to gather additional data, such as:

- Paint Usage: System can collect data on the amount of paint used by paint trucks through additional integration on the vehicle. City may consider collecting this data in the future.
- Herbicide Usage: System can also collect amounts of herbicide applied by City vehicles for vegetation management. City may consider collecting this data in the future.
- Connected Vehicle: Geotab has a feature that may allow it to communicate data from public works vehicles on vehicle location through Waze, which would in turn alert motorists using the Waze app in their cars about nearby snow plows or other public works vehicles. The City is not currently using this feature, but is aware that it could be used.
- Geo-zones: Would allow the City to see which vehicles are operating outside of a designated area. City is not considering this feature since their overall service area is not as large as other public agencies.
- Vehicle Diagnostic Reports: This report can identify when check-engine lights are present on vehicles and also track vehicle mileage, which can be used to

The central software can also provide a number of customized reports for supervisors to review based on data collected by the vehicles. As the City gains more experience with the system over time, these reports can be requested of Geotab to be created for supervisors on an automated basis for review when needed.

Geotab GO9 AVL/GPS Operational Usage

City staff noted that they view the AVL/GPS system as a tool that can help all staff better perform their operations. Vehicle operators are provided a username and password to the Geotab central software so that they can via their tablets on-board review the plow routes that they have completed during winter maintenance, which can also provide them data on how much material was used as well. City staff

noted that the system can be used as a coaching tool for vehicle operations, and that they have seen about a 25-30% reduction in the amount of salt used with this system in place. Sharing access to the system software has also helped to ease "big brother" concerns from vehicle operators about the system being used in a disciplinary manner.

During winter storm events, the City uses a route-completion component of the central software to communicate to the general public when plow routes have been completed. Vehicle location is not shared with the general public on a public facing webpage, but the route completion component does indicate which roads have been plowed. In the future, the City is considering using a time scale to indicate when roads have also been treated with materials, such as "within 2 hours", "2-6 hours", "7-12 hours", and "more than 12 hours".

The City does have 12 portable Geotab units that are battery powered and are provided to contractors that are responsible for winter maintenance snow plow operations. The Geotab units can report when a specific route has been completed by the contractor, and payment is issued based on the central software indicators that plow operators have completed operations in areas such neighborhood as cul-de-sacs. The portable units are only used in winter maintenance operations.

During a recent wind-storm in the City, the AVL system was used to monitor vehicle locations that were responding to downed trees and other damage in real-time. This type of system use will aid the City during storm response year-round as well.

Geotab GO9 System Installation and Maintenance

The City used outside vendor for installation of the previous AVL system. Since moving to the Geotab GO9 system, City staff have primarily been responsible for the installation of the AVL system for their vehicle fleet. Vehicle mechanics can plug the GO9 hardware into the OBD-II port, and they can also connect the T-harness to the GO9 hardware as well. Additional connections from the T-harness to other vehicle systems are performed by vehicle mechanics. The City obtained adapters for their heavy truck vehicles to connect with the "up/down" sensor on the vehicles, and this connection was the most time-consuming with the overall system installation.

System data is stored by Geotab and the City does not maintain a separate database to store AVL/GPS system data. Users of the software can log into the system and request data for any period of time during prior operations.

Key Benefits

The City noted the following key benefits were observed:

- Reduction of liability and tort claims from the general public regarding their operations: The City sees this as one of the biggest benefits. Vehicle operators also recognize that the system is a valuable tool to protect them.
- Safety: The system allows the City to observe if a vehicle is stopped at one location to an extended period of time which may be caused by issues related to vehicles or operators. The City can check on the operator for any problems.
- Reduction in Material Usage: The City has seen about a 25-30% reduction in the amount of salt used with the system in place.

Other General System Observations and Lessons Learned

The following are additional observations and lessons learned noted by City staff:

1. City staff encourage other agencies interested in AVL/GPS procurement to do their homework first on what they need from the system, as well as some homework on the company that they are interested in as well.
2. AVL/GPS systems are starting to move towards more of a plug-and-play type of system similar to how Geotab is being used by the City. The flexibility is allowed through use of the OBD-II port and the T-harness to connect with any type of system on the vehicle that the City desires. The prior Webtech system was more proprietary and required greater time and resource to maintain for the City.
3. Providing vehicle operators access to the system helps them to realize the benefits and minimize the "big brother" syndrome. Educating staff about how the information gathered by the system will be used is also important.
4. Having a champion to manage the program is critical. There will be technical, software, integration and other issues. It is important to have someone knowledgeable and proactive in working toward alleviating issues.

Appendix D – Case Study Interview Summary: City of Farmington Hills

Overview

A virtual interview was conducted by Ming-Shiun Lee, Mallory Crow, and Dan Nelson of AECOM and coordinated with Bryan Pickworth of the City of Farmington Hills, MI on Jan. 19th, 2022.

Farmington Hills Staff Interview

Meeting attendees on Wed. Jan. 19th included the following individuals:

- *Bryan Pickworth, Road Maintenance Supervisor*
- *Kevin McCarthy, Public Works Superintendent*

Farmington Hills Executive/Supervisor/Manager Level Interview – Jan. 19th

The City has installed an AVL/GPS system manufactured by Skyhawk Technology Systems (STS) on all of the vehicles in their fleet. The system has been used for the last 4 years, and the City is now using the second version of the system that was previously updated by STS.

The City uses this AVL/GPS equipment on three different types of maintenance vehicles:

1. About 15-16 trucks are equipped with plows, salt spreaders and liquid tanks used for roadway deicing in winter weather months. These vehicles are used in non-winter months for gravel roadway maintenance (i.e. gravel watering), street sweeping and other road maintenance purposes.
2. Between 15 and 20 additional trucks are used for general snow plowing in winter months, and general road maintenance use in non-winter months.
3. Three portable AVL/GPS units are used with street sweeper vehicles that are operated by an outside contractor.

The AVL/GPS units are all hard-wired into the City's vehicles and are not transferred between different groups of vehicles, with the exception of the portable AVL/GPS units used by contractor's assisting with street sweeper vehicles.

Key Benefits

The City stated three key areas of benefits were observed through the use of AVL/GPS system:

Safety: In case of unforeseen safety issues or emergency, the system allows the supervisors to know the vehicle and operator locations and respond to the situations quickly.

Speed Compliance: Residents may complain about maintenance vehicles being speeding. The system allows the City to verify the speed of the vehicles to respond to complaints as well as promotes operators to be in compliance of speed limits.

Citizen Complaints: In addition to speed compliance, residents may complain the City vehicles trespassing or causing damages to private properties. The system allows the City for verifying citizen claims and clearing false claims.

STS AVL/GPS System Procurement

Prior to the STS system installation, the City used Motorola two-way GPS radios that were limited to either the use of voice or data at one time. The City desired to purchase a system that could communicate data in real-time on vehicle location which would be viewable on map-based interface, as well as a system that could be upgraded as cellular technology evolved over time. In addition, the City wanted to integrate an AVL/GPS system with the RexRoth CS550 spreader controllers in use on those types of vehicles to allow the City to track materials used during winter weather events.

The City solicited for bids and received a number of responses from AVL/GPS system vendors. STS was the only vendor that was capable of integrating with the RexRoth spreader controllers with significant increases to cost, and they were selected by the City. Given that the City's vehicles are used on a year-round basis, the AVL/GPS system has also been actively used by the City during non-winter maintenance operations. The City noted that procurement documentation could be shared with the project team for future reference.

STS AVL/GPS System Field Usage

The City performs the following types of non-winter maintenance operations:

1. Gravel road maintenance. The City maintains about 22 miles of gravel residential roads with these vehicles. City vehicles are used to grade the roads, add road gravel where needed, and can treat the roads with a dust control product.
   Roadside mowing along City roads.
   Street sweeper maintenance. There are three portable AVL/GPS devices that are provided to a separate contractor for them to use during street sweeping operations.

City noted that the AVL/GPS system is always active in their vehicles throughout the year, though they have the option to disable cellular service if needed for a portion of the year. City staff noted that pictures could be taken of the equipment as needed. AECOM staff in the area will plan to visit and take pictures for a case study report in the coming months.

STS AVL/GPS System Operational Usage

City staff noted that the AVL/GPS system has been primarily used to respond to complaints from residents regarding their operations, which happens most often during the summer months. Residents may claim that the City vehicles caused some type of damage to their property. City staff can use the central software interface to illustrate to residents where their vehicles were operating during any period of the day.

The City has recently installed sensors on their from Vaisala that can gather pavement temperatures, and this equipment is integrated with the RexRoth equipment on the vehicle. The AVL/GPS system integration with the RexRoth controllers allows for this data to be collected and monitored by agency staff using AVL/GPS central software during winter weather events.

While City staff have access to the central software to monitor vehicle locations as needed, they do not utilize the software on a daily basis. Screenshots of the software can be provided by City staff for use in the case study report. The City has also provided a technical contact with STS (Walt Fischer) for further questions and any needed information on the City system.

Data on vehicle locations is not shared with the general public during either winter or non-winter periods of the year. The City does use the central software to monitor what roads have been treated by vehicles during winter weather events, and they will assign a one-word status message to roadways as "pending"/"underway"/"completed" on the City website.

Potential for Additional Operational Usage

The integration of the AVL/GPS system with the RexRoth controller is performed on the vehicles mainly to understand whether or not the controller was on or off during maintenance operations. The City is not interested in gathering the specific amount of materials used by the controller during either winter or non-winter periods given that they do not currently have a need to track that information.

The City noted that there are many additional uses that the AVL/GPS system could technically perform. These include connecting the STS equipment in the vehicle to plow and street sweeper equipment to gather up/down status, as well as roadside mowers to determine whether or not mowers are up or down in the field. In addition, the RexRoth spreader controller is also used for liquid applications during non-winter months, and the AVL/GPS system could help them with measuring how much liquid is applied during non-winter operations for dust controller or other liquid application tasks.

Another use case of the up/down status indicator could be to gather the hours of use in which a plow or a sweeper broom was in the down state. This could help to determine the effective life span of a sweeper broom, since the bristles on the broom are known to deteriorate over time.

However, the City has chosen not to use the AVL/GPS system for these additional purposes, given that they have not had problems with City staff performing non-winter maintenance activities and have not wanted to micro-manage their fleet operations. Additional staff would also be required for data collection and analysis, which City staff feels is not necessary given the relatively small size of their vehicle fleet compared to larger municipal agencies.

City staff noted that there were concerns from vehicle operators and their union about whether the AVL/GPS system would be used for disciplinary purposes. City staff were able to communicate that the system would only be used for data collection purposes, and there is a written agreement with the union that served as a compromise on how the system is used. Over time, vehicle operators have not expressed the same concerns given that the system can be used to exonerate them from complaints by the general public. City staff noted that the agreement could be shared with the team for reference.

STS AVL/GPS System Hardware, Installation and Maintenance

Agency staff from STS initially traveled to City maintenance offices to train mechanics on the process of hardware installation in the vehicles. STS trained agency through one system installation on a vehicle, and City staff completed the remaining installations of the equipment on all other vehicles. City staff will remove the AVL/GPS system from older vehicles scheduled for replacement. New vehicles are pre-wired by the vehicle manufacturer to allow for integration of the AVL/GPS system by City staff.

City staff noted that the AVL/GPS system is capable of upgrading its cellular capability as networks transition from 3G to 4G service, or from 4G to 5G service over time. A separate cellular card is plugged into the STS vehicle hardware to allow for communications of vehicle location and other information from the vehicle.

City staff noted an interior puck-like antenna is installed inside the dash of the vehicles in most cases. Larger trucks in the fleet will have a small exterior antenna that is hard-wired to the AVL/GPS system in the vehicle. The City also pays one monthly fee to STS to cover communications for all vehicles in the fleet, and this cost information can be shared with the project team for reference.

Other General System Observations

The following are additional observations noted by City staff:

1. Vehicle operators are usually assigned to their vehicles which has been helpful to reduce the potential of COVID-like spread among vehicle operators.
2. The AVL vendor contact with STS has been very helpful to City staff in assisting them with any questions they may have on the system. Software updates to the system have been performed over time as other clients of the system make requests for updates to the software. This may include special types of automated reports that can be run on a monthly basis.

3. City staff noted that STS was developing an application to gather speed data from vehicles in operation. This could be used to issue alerts through the central software when vehicles exceed a certain threshold. This could be used by supervisors in discussions with vehicle operators about reducing speeds during operations.

Appendix E – Case Study Interview Summary: Illinois DOT

Overview

Virtual interviews were conducted by Mallory Crow, and Dan Nelson of AECOM and coordinated with the assistance of Randy Neal with the Illinois Department of Transportation (IDOT) on Fri. Jan. 28th, 2022.

IDOT Staff Interviews

Meeting attendees on Fri. Jan. 28th included the following individuals:

- *Amy Eller, IDOT Engineer of Operations*
- *Laura Shanley, PE, IDOT Bureau of Operations*
- *Randy Neal, AVL/GPS System Administrator*

IDOT Executive and Supervisor Level Interviews – Jan. 28th

IDOT has implemented an AVL/GPS system on their agency's fleet of winter and non-winter maintenance vehicles which includes the following equipment:

- Vehicle radio units from Motorola (APEX model 6500 and others) installed in the vehicle for radio-based communications of both voice and data from the vehicles.
- Central software from CompassCom as the web-based interface that is viewed by agencies responsible for managing vehicle fleets and other equipment throughout the state.
- Tablet-based software from Neotreks that is only used with winter maintenance vehicles at the moment to transmit camera images taken from tablets in the vehicle of road conditions and sent over a cellular network. This is only being tested in one IDOT district currently.

IDOT staff noted that a driving factor for the procurement of an AVL/GPS for fleet vehicles was the safety of their operators. Through the use of a push button on the vehicle radio, vehicle location can be sent instantly to supervisors that can be alerted to a safety concern reported by vehicle operators. The supervisor can then communicate with the operator over the existing radio system to determine how best to respond. If the operator is not responding to the radio calls, the managers can send help to the location when the emergency button was pressed to check on the operator.

AVL/GPS System Procurements

IDOT utilized a statewide procurement contract to purchase Motorola radio equipment in 2016 for their AVL/GPS system. This also allowed IDOT to utilize an existing contract with the statewide trunk radio system referred to as STARCOM 21, which is a Project 25-compliant 700/800 MHz IP-based radio network that uses over 300 radio tower sites across the state. This radio network is utilized by public safety agencies at multiple levels, including Illinois State Police and the Illinois DOT.

IDOT staff noted that there were multiple cellular providers that had strong coverage in metro areas of the state, but this would have meant having to manage multiple cellular contracts over time. There were also gaps in cellular coverage in areas of the state at the time, and the option to use the radio network offered the greatest amount of coverage.

A demonstration with winter maintenance vehicles in District 5 (Champaign-Urbana area) was first performed with the equipment. IDOT learned through this demonstration that GPS data and other data from the vehicles could be sent through the radio network at 5-minute intervals to remove potential conflicts with voice transmissions. Non-winter maintenance operations send their data through the

network at 2-3-minute intervals. Motorola performed data tests and also made adjustments to allow for higher amounts of data transmissions.

After the demonstration in District 5 was completed, IDOT expanded the installation to other districts throughout the state and made any modifications as needed to the installation, before ending with District 1 (Chicago area) in 2019/2020. The overall rollout process was completed in about 3-4 years. The state of Illinois is currently working with Motorola to negotiate an extension to the statewide contract to support the radio network going forward.

AVL/GPS System Field Usage

IDOT has approximately 4,500 maintenance vehicles in use throughout the state that are equipped with Motorola radio hardware in their vehicles. In addition to winter maintenance vehicles, this includes paint trucks, sign shop trucks, portable scale trucks, and water pumps for use during non-winter maintenance operations.

IDOT maintains a central office computer server in Downers Grove, IL at an Illinois Tollway facility, which is where the AVL/GPS data from all vehicles and units is communicated for data storage purposes. The data is accessed by state employees that are given access to the CompassCom web-based software. Different configurations of the software interface are created for different users that use the software to monitor vehicle fleet locations.

Software users can also perform a customization of the interface to view only the information that is useful for them as well. One example provided was for snow plow operations in which a different color icon is present on the map if a snow plow is “up” or “down”. An integration between the plow sensor on the vehicle and the Motorola radio enables this communication of plow status for map viewing.

IDOT is also integrating additional data into the CompassCom software for use by staff with access to the software. This includes data from RWIS environmental stations along the roadway that would provide real-time weather data, as well as data from river gauges that can indicate river heights in areas that frequently experience flooding conditions. Information from the Illinois State Police (ISP) is planned to be added over time to assist with emergency response.

There is about 4 years’ worth of AVL/GPS data that is available to system users at the moment through the software. Older data is off-loaded onto an external hard drive for longer term storage.

AVL/GPS Operational Usage

IDOT utilizes their AVL/GPS system to support multiple types of non-winter maintenance operations as described below:

- The system has been used to improve sand-bagging operations and other resources used to support emergency response to flooding conditions. Field staff can monitor vehicle locations as they approach locations where sand bags can be loaded onto those vehicles. This allows for an improved field operation to speed up the process of loading necessary resources onto those vehicles.
- IDOT will distribute water pumps to areas of the state experiencing flooding conditions. A GPS unit is placed on the water pump to monitor the location of the pump, and it can also return the number of hours that the pump has been operational. Alerts can also be set to communicate to the central office staff on when the pumps have been operating excessively. IDOT can use the hours of service to determine when new water pumps may need to replace older models.

- Illinois State Police (ISP) can request assistance for maintenance vehicles to respond to roadway incidents. Dispatchers in the IDOT ComCenter can use CompassCom software to monitor for the location of the nearest vehicles, and can provide updates to ISP on the estimated time of arrival of those vehicles.
- Emergency Traffic Patrol (ETP) / Emergency Patrol Vehicle (EPV) fleets respond to stalled vehicles and other incidents along roadways throughout the state. If vehicles need to be towed, the location media unit (LMU) is connected to the PTO of the tow mechanism on the ETP vehicle, which allows supervisors to see that a vehicle has been towed from one area to a specific yard location.
- Paint truck vehicle fleets can be monitored to determine when paint striping began and when it ended on a specific date. There is discussion about a pilot project in District 5 to capture additional data on the amount and type of paint used by the vehicles.
- Portable scale trucks that support commercial vehicle enforcement are equipped with Motorola radio and a GPS unit. These vehicles provide portable scales that are used by the ISP in weighing commercial vehicles for weight enforcement. Supervisors can monitor the location of the portable scales and respond to requests from ISP for portable scales and enforcement.
- Sign shop vehicles are also equipped with the Motorola hardware to monitor vehicle locations and to assess progress in sign replacements in the field.

For winter maintenance, IDOT has developed a web-based dashboard through CompassCom that can present several types of operational information for supervisors to monitor during snow events. This includes a number of vehicles that are in operation, how many are spreading materials, how much salt has been dispensed, and other information. A similar type of data dashboard could also be developed to support non-winter maintenance operations if needed.

IDOT staff noted that there were some initial "big brother" concerns from vehicle operators over the AVL/GPS system. An agreement was developed with the union that noted the system would not be used to initiate discipline by supervisors, but would only be used to investigate incidents if needed. Concerns have also eased over time as the system has been used to address public complaints

System Installation and Maintenance

For non-winter maintenance vehicles, IDOT has a radio maintenance contract with various radio shops throughout the state for the installation of Motorola radio equipment in those vehicles. Most of these installations are fairly simple to complete. Radio equipment is placed in the most appropriate location for each type of vehicle and can vary based on vehicle type. All equipment installed in the vehicle is dedicated to each vehicle and does not get transferred to other vehicle types.

Larger winter maintenance vehicles are pre-wired by a vehicle manufacturer so that radio shop technicians can insert the radio equipment when the vehicle arrives for use. As older maintenance vehicles are phased out of the fleet, radio shop technicians will remove the Motorola radio equipment and place it inside the newer replacement vehicles that arrive pre-wired from the manufacturer.

Motorola radio hardware from the vendor costs approximately $5,000 per device, and the antenna for communications costs about $50. The costs from Motorola for this equipment were also discounted given that such a large amount of devices were procured. The overall cost for system maintenance is approximately $900,000 on an annual basis. This includes maintenance of the Motorola vehicle hardware, the AVL data server, the CompassCom software application, and any other AVL/GPS equipment procured from Motorola.

Other General System Observations

The following are additional observations noted by IDOT staff:

1. Start the deployment of the AVL/GPS where there is "buy-in" and support in place for the project. As the concept is proven, build out from there to support other areas.
2. The ability to document the amount of emergency response and support provided during flooding season has been a big benefit to the use of the system for non-winter maintenance operations.
3. IDOT noted that their approach to AVL/GPS deployment for their fleet was to procure the equipment first and address various needs from internal agencies as they arose over time. While the system has proven very beneficial, an alternate approach of determining agency needs first, followed by procurement, might be a more desirable approach for agencies that are considering a similar type of AVL/GPS deployment.

Appendix F – Case Study Interview Summary: Alabama DOT

Overview

Virtual interviews were conducted by Ming-Shiun Lee, Mallory Crow, and Dan Nelson of AECOM and coordinated with the assistance of Andrew Harry with the Alabama Department of Transportation (ALDOT) on Thurs. Jan. 20th, 2022.

ALDOT Staff Interviews

Meeting attendees on Thurs. Jan. 20th included the following individuals:

- *Andrew Harry, State Traffic Operations Engineer*
- *William Butler, Guntersville Area Maintenance Engineer*
- *Jacob Hodnett, ALDOT Agronomist*
- *Howard Peavey, ALDOT Agronomist*
- *Phillip Day, Assistant Region TSMO Engineer*
- *Zach Bennett, Guntersville Area Asst. Maintenance Engineer*

ALDOT Executive/Supervisor/Manager Level Interview – Jan. 20th

ALDOT has two separate AVL/GPS systems implemented on their vehicle fleets that are used for different agency purposes. These are described below:

1. Trimble – System used with herbicide spray vehicles on a statewide basis. Tablet devices are installed in the vehicle and connected with spray equipment to manage treatment amounts applied along roadway segments. Central software used for monitoring vehicle locations, understanding what areas have been treated, and gathering vehicle data during or at the end of a vehicle shift. Still working with vendor on reporting additional information such as targeted plants and type of herbicide used.

2. Comet Tracker – System used with other vehicle types (light-weight vehicles, maintenance vehicles/trucks) on a statewide basis. Small hardware device is connected with on-board diagnostic port of the vehicle. Central software used by agency staff for monitoring only the vehicles applicable to their department.

Trimble/Comet Tracker System Procurements

ALDOT procured the Trimble AVL system as a sole source procurement in which the Trimble software was a driving factor for the system procurement. System is typically used in the agriculture industry and the vendor is working with ALDOT to adjust for DOT needs. ALDOT had also required that Trimble integrate with in-vehicle equipment on herbicide spray vehicles, and Trimble had the capability to complete the integration for the agency. ALDOT staff noted that they could provide documentation for review on how the sole source procurement was completed.

ALDOT separately procured Comet Tracker AVL/GPS devices through a state contractor for installation on light-weight vehicles and other maintenance vehicles/trucks. Procurement of the devices is through a state contract with a regional cellular service provider (Southern Linc) that provides the Comet Tracker hardware devices for each vehicle for a monthly service charge. ALDOT noted that monthly costs from Southern Linc as a provider could be provided for reference. Comet Tracker devices are manufactured by a separate company named ActSoft, and the devices can be used elsewhere with other cellular service providers in a similar manner.

Trimble AVL/GPS System Field Usage

ALDOT selected Trimble to provide tablet devices for herbicide spray vehicles that would be required to integrate with existing spreader and spray equipment on the vehicles. The tablet devices have a cable interface with an on-board device that can control the operation of spreader and spray equipment. This allows an operator in the passenger seat of the vehicle to monitor the amount of herbicide application being applied, and to make adjustments as needed during treatment.

ALDOT staff noted that the Trimble devices could also be used during disaster cleanup and recovery efforts to record how many cubic yards of area has been cleared, when the herbicide vehicle is used for other maintenance tasks. In addition, ALDOT is working to gather ground speeds of their vehicles through the Trimble device when those vehicles are used to treat roads during winter weather events.

Trimble devices can be connected to a wireless Mi-Fi mobile hotspot device on the herbicide spray vehicles for the purpose of data reporting in near real-time to a central software system. Vehicles can also upload their data at the end of their shift using the Wi-Fi capability of the mobile hotspot in the vehicle garage that has a wireless network for receiving data from the Trimble devices.

Comet Tracker AVL/GPS System Field Usage

Comet Tracker devices are primarily used for fleet management purposes on state vehicles. These devices use a cellular signal through the service provider (Southern Linc) to transmit data on the vehicle location as well as vehicle mileage. Vehicle operators do not have a tablet or other device connected with the Comet Tracker, and the device is often not visible to vehicle operators in the field.

Trimble AVL/GPS Operational Usage

ALDOT staff noted that a main operational goal with the Trimble devices is to automate the process of environmental reporting by operators of herbicide spray vehicles. Time spent on hand-written reports by operators can range between 30 and 90 minutes for each trip made by the vehicles for treatment. Information from these reports then need to be entered also by hand into a state Maintenance and Management System (MMS), which can create additional opportunities for human error in the data reporting process.

ALDOT noted that the Environmental Protection Agency (EPA) has regulations that need to be followed with respect to how much herbicide can be applied in certain areas, such as a five-year record of documented activities showing target plant(s) and chemicals used to treat. The hand-measured reporting process does help to maintain compliance with EPA regulations, but does require a great amount of time by field staff.

Trimble AVL/GPS devices are currently being used by ALDOT on herbicide spray vehicles to electronically collect information that can be stored automatically on operator reports. ALDOT staff provided the spray report to Trimble staff and requested them to be able to electronically record all of the same information in an automated report that can be gathered at the end of their shift.

ALDOT is also currently working on two separate efforts to complete the automation of the reporting process: 1) updates to the state's central MMS to improve connections with other state agencies, and 2) an Application Programming Interface (API) that can input data from the electronic operator reports on the Trimble devices into the MMS in a manner that is in compliance with EPA regulations. ALDOT noted that they plan to develop the API internally for integration of the Trimble system with the MMS, but it may be possible for Trimble to develop the API as well.

This process of automated reporting can have the effects of reducing the chances of human error in operational reporting while allowing more time to operators to focus on safely and efficiently performing herbicide spray treatments. Currently, both hand reporting and electronic reporting are being done, though once the integration with MMS is complete, it is envisioned that automated reporting only will be needed to comply with EPA regulations.

ALDOT supervisors can also use the Trimble software to visually view which areas of roadside vegetation have been treated by vehicle operators. This type of summary can be used to assist with reporting and provides a visual representation for operators to determine what areas still require treatment.

Comet Tracker AVL/GPS Operational Usage

ALDOT staff noted the Comet Tracker system is administered by the state DOT and the department's fleet management system. Specific departments can be given access to the system's central software to monitor the locations of vehicles that only apply to their department. The software is used internally by ALDOT staff only, and vehicle location information is not shared with the public or other external agencies.

ALDOT noted that the Comet Tracker can be used for the following operational purposes:

1. Reports on vehicle mileage that exceed certain thresholds. Different types of vehicle maintenance can be automatically scheduled, which can reduce the amount of paper reporting by supervisors, help to extend a vehicle's use life, and allow for improved fleet management.
2. Geo-fences can be set up through the central software package to define areas in which the vehicle should remain, and alerts can be created if the vehicle travels outside of the geo-fences.
3. Supervisors can indicate on the state's 511 website on which roads have been treated during winter weather events. This can help to inform the public on which roads are safe to travel during those types of events.

ALDOT has noted that they have been very well commended for how the system has been used for state operations.

In addition, ALDOT staff noted that vehicle operators have often times been exonerated from claims of vehicle damage by the general public through the use of the system. Central software reports can identify the location of state vehicles at specific locations and times, which can be provided to motorists that may claim an ALDOT vehicle was responsible for damage to their vehicles.

Trimble/Comet Tracker System Installation and Maintenance

ALDOT staff noted that installation of the Trimble tablet device and its integration with spreader equipment is performed by the dealer that provides herbicide spray vehicles. This removes the potential for error by agency staff in the installation process. The Trimble devices are provided by an agricultural company named Vantage South that specializes in precision agriculture through the use of AVL/GPS technologies. Mi-Fi mobile hotspot devices are also provided from Vantage South for reporting to the central software.

ALDOT staff noted that Trimble was primarily used in agricultural settings in the south before ALDOT recommended the system's use for use with the automation of herbicide spray reporting. ALDOT staff noted that there have been very few issues with the operation of the Trimble system. The only known issue discussed by staff was related to a software upgrade that ALDOT staff adjusted to by altering the use of the system. Calibration of the Trimble hardware on herbicide spray vehicle is done at the start of every shift to ensure accurate usage of herbicide spray by the vehicle during its operation.

ALDOT staff noted that pictures of the Trimble hardware can be provided for use in illustrating how the system is integrated with other equipment on the vehicle. Other pictures/screenshots of the Trimble central software used in monitoring and reporting can also be provided for reference. ALDOT staff will also provide a technical contact with Vantage South for any additional technical questions.

Comet Tracker hardware is installed by vehicle yard management staff on the on-board diagnostic port of the vehicles. Given that the hardware is not visible to vehicle operators, there are no reported maintenance issues with the system.

Other General System Observations

The following are additional observations noted by ALDOT staff:

1. Vehicle operators have not expressed "big brother" types of concerns with either the use of the Trimble or the Comet Tracker for disciplinary purposes.
2. ALDOT has found that their request for automated reporting is helping to expand the horizon of the equipment vendor which typically works in agricultural settings.
3. Roadside mowing is contracted out by ALDOT to other agencies. AVL/GPS systems are not used to monitor mowing operations.

research for winter highway maintenance

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