**Project 16-01: Utilization of AVL/GPS: Case Studies**

**Summary of Colorado DOT In-Person Interviews**

***Overview***

Interviews were conducted by Ming-Shiun Lee and Dan Nelson of AECOM and coordinated with Kyle Lester of the Colorado Department of Transportation (CDOT) on January 9th and 10th, 2018.

***CDOT Staff Interviews***

Meeting attendees throughout the day on Tues. Jan. 9th included the following individuals:

* + *Kyle Lester, Director of Highway Maintenance*
  + *Paul Fox, Heavy Fleet Administrator*
  + *John Lorme, Region 1 Superintendent*
  + *Al Martinez, Region 1 Deputy Superintendent*
  + *David Johnson, Winter Operations Manager*
  + *Chris Volkert, Equipment Asset Manager*
  + *Jeff Tatkenhorst, Region 9 Highway Maintenance Superintendent*
  + *Mike O’Neill, Region 1 Deputy Director of Maintenance*

Meeting attendees throughout the day on Wed. Jan. 10th included the following individuals:

* + *Kyle Lester, Director of Highway Maintenance*
  + *Ryan Rice, TSM&O Division Director*
  + *John Lorme, Region 1 Superintendent*

***CDOT IT Operations Level Interviews***

Group met at the CDOT Maintenance Training Offices in Golden, CO on Tues. Jan. 9th to discuss how CDOT has implemented AVL / GPS technology for their vehicle fleet. CDOT maintains a heavy vehicle fleet of approximately 1,800 vehicles, which includes about 1,200 snow plow vehicles. These vehicles have an AVL system provided by Zonar Systems that features a ruggedized tablet within the snow plow that provides an interface for drivers to use for logging into their specific route. CDOT drivers utilize a pre-assigned ID card and tap it to the tablet to log into the tablet to perform various functions. The tablet also performs a number of other tasks, namely electronic pre-trip and post-trip inspection reporting which has replaced paper reporting that was previously done by CDOT drivers.

The main software interface provided by Zonar is known as Ground Traffic Control, which is used by CDOT Administrators to assign other CDOT staff different levels of access to the software interface. This includes supervisors, mechanics, and drivers as users of the software to perform various functions. One lesson learned early on in the deployment was the high frequency with which users were notified of vehicle diagnostic issues requiring maintenance. When an issue was detected, an email notification was sent to supervisors and mechanics. As a result, a huge amount of notifications were generated and sent to those users regardless if the issues were newly detected or previously communicated. To reduce the amount of notifications yet help users keep tracking of issues need to be resolved, CDOT worked with Zonar to create a weekly report that provided a single report with all vehicle diagnostic issues. Major diagnostic issues are assigned a red flag and still provided via email to mechanics whenever they are detected. Mechanics are then required to address red flag issues and progress of completion is tracked until completion.

CDOT has also recently provided the location of snowplows on a public facing website to increase the public transparency of winter maintenance operations, available at: <http://www.cotrip.org/snowplow.htm#/snowplow>. The locations of the snow plows are made available through the sharing of the Application Programming Interface (API) by Zonar with CDOT, so that CDOT can request latitude / longitude coordinates of vehicles and display them on a map of the state. Bread crumb trail points on where snow plows have been is also shown when clicking on a snow plow icon on the map. Snow plows would disappear from the public facing website after 15 minutes of inactivity (i.e. when the ignition is turned off). CDOT was still exploring different solutions to determine inactive vehicles.

A separate AVL system has also been installed on the CDOT light vehicle fleet which is provided by Verizon known as NetworkFleet. Light vehicles operated by CDOT are not required under federal regulations to have the same pre-trip and post-trip reporting, thus Verizon NetworkFleet is an AVL system used by light vehicles whereas Zonar is implemented on heavy vehicles.

In addition to vehicle location data, the Zonar system collects engine idle time, vehicle speed, vehicle health and diagnostics, and inspection data and timestamps. Data required for the Federal Motor Carrier Safety Administration (FMCSA) compliance were retained for six months, per FMCSA requirements. For light duty vehicles, Verizon made the data available in a more user-friendly environment for a period of 90 days. Only raw data were accessible after the 90-day period. Data related to winter maintenance operations were stored in MDSS. CDOT did not save any data generated from those systems on its server due to liability concerns.

Group also discussed cellular coverage in areas of the state which still has some unacceptable gaps in coverage where snow plows do operate. CDOT has noted that this is a drawback to the reliance on cellular technology, which may cause long periods of time between updates on vehicle location and other information. CDOT has noted this on its public facing webpage so that the general public is aware of the potential delay in the update of vehicle locations.

It was noted that Zonar Systems works exclusively with AT&T as a cellular network provider. Although different cellular providers may have stronger coverage in other areas of the state, CDOT noted that some areas of the state are difficult in terms of elevation and climate, which are not conducive to the use of any kind of cellular network coverage.

Group noted that the Zonar AVL system, like many other AVL systems, is reliant on third-party mapping sites, such as Google, for integrating maps into its software interface. This may result in errors generated from alert-based reporting that is a feature of the Zonar. For example, alerts are generated for snow plow vehicles traveling over 50 MPH along a roadway segment. If a snapshot of the vehicle location is taken while that vehicle is traveling 40 MPH but crossing over / under a road with a 20 MPH speed limit, a high-speed alert will be generated and sent to a superintendent. CDOT staff have learned to spot these types of errors in the system over time.

Other alerts can be generated from the Zonar system on idle times in excess of a number of hours and vehicle health reports in terms of vehicles that have not had pre-trip or post-trip reports completed. CDOT has learned how to balance the thresholds of these alerts to generate the appropriate number of alerts for mechanics and for superintendents. CDOT staff spoke highly of the idle time alerts, which they felt helped to correct excess fuel consumption and reduce maintenance costs early on in the AVL system testing process. It was estimated that the overall savings on these two items in the first year of the system’s use exceeded the overall costs of the AVL system installation for the fleet.

CDOT staff spoke about Cirus spreader controllers on newer maintenance vehicles that have been integrated with the Zonar AVL system. The integration process between Zonar and Cirus was initially hampered by the length of time required for both sides to come to an agreement on a Memorandum of Understanding (MOU) that would protect the intellectual property of both companies. A separate truck building company used by CDOT for up-fitting the vehicle chassis and all equipment was able to bring representatives of both Zonar and Cirus together to determine how best to complete the integration process. In term of the AVL equipment installation, CDOT noted that a pre-build meeting was conducted with the truck building company to ensure installation standards. CDOT did not experience any issues with the AVL equipment installation.

These newer vehicles are also presenting automated treatment recommendations on the Zonar tablets through a separate agreement between Zonar and Iteris related to MDSS system operations for CDOT. Snow plow operators are still provided the independence to determine the level of treatment based on existing conditions and their judgements, given its diverse geography within the state that can make it difficult for weather forecasting services to predict the duration and intensity of winter storms for specific regions, areas or corridors.

One of the lessons learned from superintendents and managers is for the agency to best understand what they want from the AVL system to meet their agency’s needs. CDOT noted that the needs and goals for the AVL/GPS program were not clearly identified initially. They now have a better understanding of their needs through the implementation and utilization of the system. CDOT also emphasized the importance of training and noted that properly trained personnel resulted in good results and better usage of the system. Another lesson learned was to have more training performed at the beginning of the program. CDOT performed some training at the beginning of the program but felt that more training up front would facilitate buy-in and proper use of the system. It was also noted that CDOT staff at an administrative level on the software side of the system were still learning the system at the time when supervisor and operator training sessions where carried out. CDOT staff with the software administrative rights were unable to demonstrate the smooth usage and operations of the software, which resulted in speculation in system usefulness and user resistance.

CDOT conducts training to snow plow operators on the system annually. CDOT felt that making recordings of the training available would be helpful for new snow plow operators. In addition to the annual training, CDOT planned to conduct traveling road shows through the state to provide additional training and raise awareness. CDOT would also like to perform additional training to managers to help them with interpreting reports and maximizing their knowledge to the system.

***CDOT Supervisor / Manager / Technician Level Interviews***

Group continued to meet at CDOT Maintenance Training Offices in Golden, CO on Tues. Jan. 9th to discuss how the Zonar AVL / GPS system was procured for winter maintenance operations.

CDOT is split into eight different maintenance sections throughout the state. Within each section, CDOT winter maintenance staff is structured into the following general positions:

Section Superintendent: Responsible for overseeing winter maintenance activities within the section in terms of response to winter storms. May be responsible for allocating some of the section’s resources to other sections of the state in the event of large winter weather storms.

Section Supervisor: Responsible for monitoring how multiple vehicle operators within the section have allocated resources to plow roads within a specific area of that section. Reports to Superintendents and communicates with vehicle operators as needed during winter events.

Vehicle Operators: Responsible for overseeing multiple snow plow drivers performing along their assigned snow plow routes within the section.

The group acknowledged that there was some reluctance among vehicle operators to accept the AVL system equipment given concerns about the system potentially being used for disciplinary reasons. It was noted that CDOT gained buy-in from drivers over time as drivers realized that the Zonar AVL system could be used to protect them from claims of damage caused during winter storms by CDOT snow plows. CDOT noted that to gain operators buy-in, support from supervisors as well as training to supervisors for proper use of the system is critical. When communicating with operators, it is essential to focus on communicating the benefits (such as for their protection from claims and personal safety) and making it clear that the system is not a tool for micro management or disciplinary actions.

Among the greatest benefits to the use of the system is an increase in situational awareness of how staff are responding to winter storms and an ability to present the response to executive management in real-time on vehicle locations. Other benefits identified by CDOT staff include:

* System generated maintenance alerts helps with proper diagnostic and repairs. This in turns saves money and promotes timely repairs.
* Alerts on long vehicle engine idle time helps reductions in idle time, fuel consumption and negative emission impacts.
* The system has abundant reporting features that help not only in situational awareness but also in improving resource management, staff management and operational efficiency.
* The system had positive impact on driver behaviors such as promoting speed compliance and minimizing improper use of the equipment.
* The system has been used to protect drivers from false/erroneous accusations by the public.

In addition to the above benefits, CDOT would like to establish a performance management program to systematically evaluate and document the benefits of the AVL/GPS and fleet management system. A performance dashboard was highly desired. CDOT noted that due to lack of sufficient data to measure improvements, cost savings and other measurable improvements have not been assessed. CDOT indicated likely performance measures and goals would include:

* Reduction in equipment down time
* Increase in reliability
* Reduction in repair costs
* Fuel savings
* Road surface friction

The subject of treatment recommendations through MDSS was discussed with the group. Prior to 2014, CDOT procured an AVL/GPS system (from iwapi) along with MDSS under one contract. Since 2014, the MDSS services were procured under a separate contract with Iteris. CDOT currently has a number of fixed weather stations providing air and pavement temperatures back to a central office for the determination of treatment recommendations. Vehicle operators are still provided the independence to determine the level of roadway treatment based on existing conditions, given the differing number of climates and regions within the state that can make it difficult for weather forecasting services to predict the duration and intensity of winter storms.

CDOT is conducting a pilot study on using friction sensors in lieu of pavement/air temperature sensors. CDOT felt that pavement friction provides a better picture on road surface conditions. Upon successful testing, CDOT plans to integrate friction sensors with the AVL system and expand the installation statewide. Data from friction sensor will be input into MDSS.

CDOT also discussed an ongoing project being conducted under the agency’s RoadX program that provides funding for new and innovative transportation projects in the state. Under the program, Verizon is partnering with two separate companies – Cradlepoint and Panasonic – to implement a system that would communicate real-time images and video from snow plow vehicles to a central office that could view roadway conditions and communicate back to the vehicle through in-vehicle equipment. Cradlepoint is providing an in-vehicle wireless communications router that is wirelessly connected to an in-vehicle dashcam provided by Panasonic, along with other in-vehicle equipment such as spreader controllers and temperature sensors. The overall goal of the pilot project is to send and receive all data through the Cradlepoint router and improve the efficiency of in-vehicle communications. Depending on the overall success of the project, CDOT may roll it out on a larger scale in future years.

***CDOT Executive Level Interviews – Wed. Jan. 10th***

Group met at the CDOT Headquarters offices in Denver to discuss the history and processes followed in the installation of the AVL / GPS system for the CDOT heavy and light vehicle fleets.

Prior to 2014, CDOT had previously implemented an AVL / GPS system provided by Iwapi on a number of snow plow vehicles throughout the state. Each maintenance section decided on the quantity of vehicles within that section to equip with an AVL / GPS system. This resulted in some sections having more vehicles equipped with an AVL / GPS than others. While the system had provided benefits to some sections of the state with an increased awareness of winter maintenance operations, a larger statewide view of how multiple sections were responding to winter storms was not possible with different levels of acceptance by different sections of the state.

Implementation of an AVL/GPS system on CDOT fleet was driven by a desire to implement a system that could assist in fleet management and operations. CDOT primary needs for such a system included:

* An automated feature to reduce administrative burden for pre and post trip inspection.
* A robust vehicle diagnostic program to support vehicle health monitoring and preventive maintenance.
* A fuel management program to improve fuel efficiency and fleet utilization.

An AVL/GPS system was an element of a fleet management systemthat CDOT desired to implement. CDOT began the preparation of a Request for Proposals in 2014. The overall goal of the procurement would be to select one vendor to supply hardware and software equipment for both the CDOT heavy vehicle fleet and light vehicle fleet.

CDOT also had been conducting a number of small AVL / GPS system demonstrations in 2014 with various vendors that were interested to demonstrate their system’s functionalities to CDOT in advance of any future procurement. AVL vendors included Zonar and Verizon NetworkFleet among others, provided their systems for demonstration free of charge. These demonstrations provided some insight into the capabilities of the current systems and how they could achieve CDOT goals and objectives related to fleet management. Early results from the demonstrations revealed that some vehicles had been idling with engines running for excessive periods of time, resulting in both excess fuel consumption and increased maintenance costs. The awareness of the issue resulted in the prevention of those instances in future maintenance operations, resulting in a large amount of operational savings to CDOT. This prompted CDOT to reconsider their priorities and realize an opportunity for improving fleet and fuel efficiency.

Upon review of the various systems being demonstrated in late 2014, Colorado DOT executive level managers decided to accelerate the installation timeline of AVL / GPS technology on CDOT snow plows beyond the previously planned timeline as part of the RFP process. Colorado state law allowed CDOT to leverage an existing master services agreement already in place between Zonar and the City and County of Denver, which enabled CDOT to procure a Zonar AVL system for the heavy vehicle fleet that could perform both vehicle monitoring and automated pre-trip and post-trip vehicle inspections. CDOT used a separate existing contract with Verizon to procure a NetworkFleet system for the light vehicle fleet, which did not have the same requirements for pre-trip and post-trip reporting.

Although the procurement process resulted in two different AVL / GPS systems, CDOT was able to meet the accelerated timeline and deploy the Zonar AVL system on its heavy vehicle fleet for use in 2015. CDOT was also able to justify the higher cost of the Zonar AVL system based on the overall fleet management costs managed by the agency. CDOT currently manages a combined heavy and light vehicle fleet with an estimated value of about $1 billion, and viewed the overall costs related to fleet management as greater than that of the winter maintenance operations estimated at about $77 million for the current winter season.

Zonar’s previous clients included commercial vehicle fleets and other agency fleets, but they were relatively new to winter maintenance operations performed by state governments. As such, CDOT has been working with Zonar to address specific issues related to winter maintenance operations that were new to Zona. Such issues included: integration with various spreader controllers, SAP software and dashcam, as well as development of specific reports for operations and performance management. CDOT was also encouraged by the willingness of Zonar to work with CDOT to perform additional integration of their AVL system with other systems, namely vehicle spreader controllers and an existing SAP system currently used by CDOT for employee timesheets and issuing work orders on items requiring maintenance, such as roadside guardrail or other roadway assets managed by CDOT.

However, delays to the integration process arose from the length of time required to develop Memorandums of Understanding (MOUs) that were requested from legal teams of both Zonar and SAP. The MOUs were requested to protect the intellectual property developed by both companies from potentially being shared with competitors through the exposure of those systems to each other in the process of working for CDOT. Although discussions had taken place between Zonar and SAP, CDOT eventually instructed Zonar not to proceed further with an MOU given the length of time it was taking to come to an agreement between both companies.

Additional challenges resulted from other MOUs requested of Zonar prior to integrating with spreader controller manufacturers. This integration process was eventually assisted by a local company that CDOT was utilizing for up-fitting of trucks ordered by CDOT with winter maintenance equipment. The company brought Zonar field staff together with Cirus Controllers as a manufacturer of some of CDOT’s existing spreader controllers. Integration testing by the truck company of the communications between the systems resulted in an accelerated completion of the integration that otherwise would not have been possible. At the moment, Cirus controllers have been integrated with Zonar on about 200 snow plow trucks, with newer snow plow vehicles being upfitted by the trucking company with that integration already performed.

CDOT noted that these and other challenges with Zonar have caused CDOT to re-assess how they should proceed with AVL / GPS system technology on both their heavy and light vehicle fleets in future years. With the current contract with Zonar expiring in 2019, a new RFP is likely to be developed in 2018 that will present a refined set of CDOT objectives with respect to on-board AVL / GPS technology and integration with other systems. The RFP would likely place the responsibility of AVL / GPS system integration with other systems with a single vendor that would be accountable for the overall installation that would achieve CDOT’s desired level of system integration.

CDOT recognized the Zonar system had a lot of potential and capabilities. They acknowledged that CDOT has not utilized the system to its full capabilities and continued exploring its potential and capabilities. However, CDOT also noted the lack of staff has been a key challenge that hindered their ability to explore the system capabilities within a desired timeline.