Plug-and-Play Initiative: Phase II

SRF Consulting Group, Inc.

CLEAR ROADS
research for winter highway maintenance

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Plug-and-Play Initiative: Phase 2

Final Report

Clear Roads

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16. Abstract
Clear Roads has undertaken an initiative to establish a Plug-and-Play protocol that fosters interoperability between various winter maintenance equipment and a point location (central office). This report documents the data types and communication methods to allow communicate between the plow equipment and a point location. By implementing concepts discussed in this report, winter maintenance agencies will strive to allow interoperation between various equipment vendors through the use of open protocol standards like the National Transportation Communications for Intelligent Transportation System Protocol (NTCIP) and Maintenance Decision Support System (MDSS). Additionally, they will gain the ability to interoperate between agencies by transmitting data in an open and consistent format. The project included a literature review, an agency survey, freight industry survey, and the development of a list of data types to be considered for inclusion in the Plug-and-Play standard. Currently, no single protocol addresses all the needs identified and it was deemed to be not feasible to incorporate such needs into any given protocol. Instead, it is recommended to implement a "family" of open standards that include appropriate data types.

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Executive Summary

Clear Roads has undertaken an initiative to establish a Plug-and-Play protocol that fosters interoperability between various winter maintenance equipment and a point location (central office). Phase 1 of this initiative established a protocol for automatic vehicle location (AVL) equipment to communicate with spreader controllers. This report covers the findings of Phase 2, which determined the data types and communication methods to be able to communicate between the plow equipment and the point location.

By implementing concepts discussed in this report, winter maintenance agencies will strive to allow interoperation between various equipment vendors through the use of open protocol standards like the National Transportation Communications for Intelligent Transportation System Protocol (NTCIP) and Maintenance Decision Support System (MDSS). Additionally, they will gain the ability to interoperate between agencies by transmitting data in an open and consistent format.

The project included:

- A literature review to understand the state of the practice and learn about other forward-looking industries to understand potential future data types.
- An agency survey to understand what data types are currently in use and which data types are most important. Data types found to be the most important should be considered for mandatory inclusion in appropriate protocols. Other data types should be considered for optional inclusion.
- A freight industry survey to understand how other industries handle data transmission and protocols. The freight industry generally uses proprietary protocols although data management devices often support hardware from multiple vendors.

During the project, the concept of a single protocol that fulfilled the Plug-and-Play needs was discussed. However, no single protocol addresses all the needs identified and it was deemed to be not feasible to incorporate such needs into any given protocol. Instead, it is recommended to implement a "family" of open standards that include appropriate data types. **Clear Roads should maintain a list of the family of protocols that qualify as "Plug and Play."**

A series of recommendations was developed to foster the implementation of such a family of Plug-and-Play standards.

- Transportation agencies should work in concert with FHWA as FHWA can influence automotive industry groups to use the systems engineering process and make sure the road/weather parameters are not overlooked.
- Transportation agencies should work together to develop procurement documentation that includes consistent protocol standards. This may encourage the vendor industry to shift to meet the Plug-and-Play standards. Standardized boilerplate procurement language used by many agencies can facilitate this transition to Plug-and-Play standards.

- Winter maintenance stakeholders within agencies should get buy-in from agency IT departments to mitigate procurement and deployment issues related to such use.

By putting these Plug-and-Play standards recommendations into practice, agencies can help move the industry to more open protocols and begin to receive the benefits of the Plug-and-Play concept.

Introduction

Many public agency winter maintenance programs use snow plows with increasing numbers of sensors and sophisticated vehicle electronic systems. These systems have been augmented with data collection capabilities to assist plow drivers and maintenance supervisors to maintaining the roads in more effective and efficient ways. While early sensors displayed information to drivers directly, the need has emerged to aggregate the data and transmit it to a point location so that it can be useful on a system-wide basis. Various departments of transportation and vendors have approached this topic with different strategies.

Centralized data management systems can use this data to assist road maintenance decision makers or assist with fleet management. However, the protocols for communicating these data are not standardized which results in difficulties extracting data from the vehicle. This report documents research related to these protocols and data types.

Literature Review

The literature review documented the current practices related to communication between mobile vehicles that collect data and a central office. Various parts of the industry have formalized these protocols to different extents according to their needs.

The literature review showed the vast number of different sensors and technologies winter maintenance and transit operators have implemented. This variety demonstrates the challenging task required to develop an all-encompassing protocol that is compatible with such a great number of sensors and data types.

Background

Network communication methods are a complex subject. People use various network communication methods every day and generally regard the network as a single link. However, most communication methods have several layers of functions. The Open Systems Interconnection (OSI) model helps explain how various communication methods and protocols compare and contrast. Figure 1 shows how these layers are structured in terms of potential communications from a truck to a separate data aggregation point.

Clear Roads members need a method for on-vehicle devices to communicate with a point location in a way that is compatible between vendors and across agencies.

This project included the study of on-vehicle systems and head end systems to provide a recommendation for relevant options for all layers as well as a list of data types to be included in OSI Layer 7.

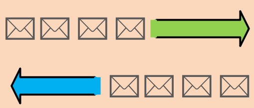
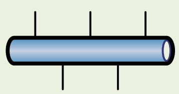
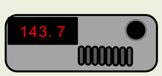
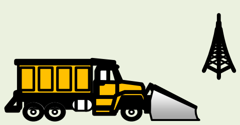
	Layer	Examples	Function	Comments
<Tag DATA /Tag>	7 Application	NTCIP VISCA Others	The "language" of the data exchange between devices, including data types, formats, tags and syntax.	Layers 5 and 7 are closely related and decisions are driven by specifics of the Layer 7 protocol
00101001010101001 2 ABCDEFG AES-2	6 Presentation	ASCII Unicode Binary (JPEG, MP3, etc.)	Structure of the data that will be exchanged, such as Unicode for alphanumeric data from sensors and AVL, JPEG for images, encryption types, etc.	Determined by the nature of data – Unicode for tabular info., binary for others
 ->DESCRIBE OK<- ->PLAY	5 Session	Real-Time Protocol Session Initiation Protocol	Allows devices (like AVL controllers) and host systems to identify the types of data they can exchange and the commands for requesting data.	
	4 Transport	Transport Control Protocol Universal Datagram Protocol	Defines error correction, re-try parameters how data is "packetized" or broken up and re-assembled on the network.	Determined by the nature of data – guaranteed delivery for tabular info., best effort for streams
	3 Network	IP addresses	Assigns a flexible, system-defined address to a communications device.	
	2 Data Link	MAC Address (WAN) ESN (Satellite) IMEI (Cell Networks) Others	Identifies a specific communications device to the network so that it can be addressed by the layers above.	Ideally, these are transparent and interchangeable to the system
	1 Physical	UHF Radio 2.4 GHz (for WiFi) L-Band (Satellite, etc.) 2100 MHz (cellular) Others	Defines the physical connection, modulations and signaling methods of a data connection between the vehicle and an external network.	

Figure 1. OSI Layer Model and Examples

Mobile/Point Location Data Communication Architecture

The simplified system architecture shown in Figure 2 presents a visualization of the communication system. This diagram shows that a data management controller is the interface between the on-vehicle Plug-and-Play devices and the communications system. The items shown are "logical" (rather than physical) and these functions may reside in the same hardware device or separate ones.

The connection shown in black represents alternative methods for devices that may not be suitable for integration into the Plug-and-Play protocol family, such as Real Time Streaming Protocol (RTSP) used for video. If the protocols are designed to primarily transmit small data payloads, it may not be conducive for high-bandwidth data, such as streaming video. However, the Plug-and-Play family may incorporate references to these data including a link to a video stream or links to images.

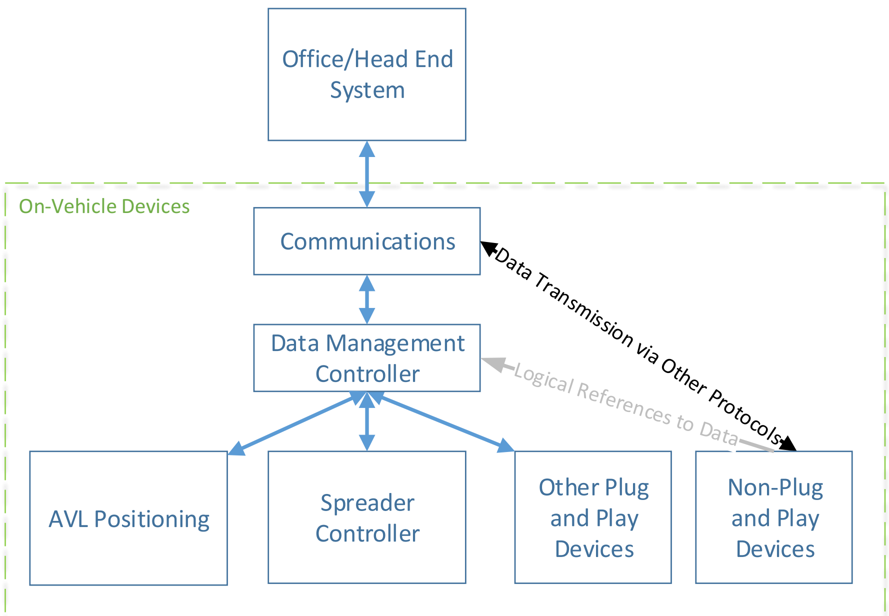


Figure 2. Plug-and-Play Architecture

Existing Data Transmission Protocols

Industry Standard Protocols

Plug-and-Play Initiative: Phase I

Phase I of the Plug-and-Play Initiative developed the "Preliminary Clear Roads Universal In-Cab Performance Specification and Communications Protocol" in 2014. This protocol enables communication "between compatible Automatic Vehicle Location (AVL) devices and antiicing/deicing Joystick and Spreader Controller systems."[1] This protocol includes a pinout specification, device compatibility requirements, and specific syntax (computer code written for computer systems to understand and process) for devices to use. Currently, this protocol exclusively facilitates communication between the AVL systems and spreader controllers.

NTCIP

The Intelligent Transportation Systems (ITS) industry has established the NTCIP protocol. This protocol is administered by National Electrical Manufacturers Association (NEMA) and has wide adoption among public agencies and vendors. Often, public agencies specify that components need to be NTCIP compliant as a way of establishing a minimum level of communications capability and interfacing with other ITS systems. NTCIP's Framework is shown in Figure 3. [2]

NTCIP section 1204 presents an Environmental Sensor Station Interface Standard. This section is devoted to weather and transportation-related "objects" and includes location-based objects which are important for a mobile environment. Thus, this standard already includes the needed basic AVL data that is needed to link environmental/sensor readings with location.

Briefly, the process for integrating new protocols into NTCIP is for an industry organization (for example, Clear Roads) to NEMA and recommend items to be integrated into NTCIP. NEMA's engineers then develop the specific protocol syntax for inclusion into NTCIP.

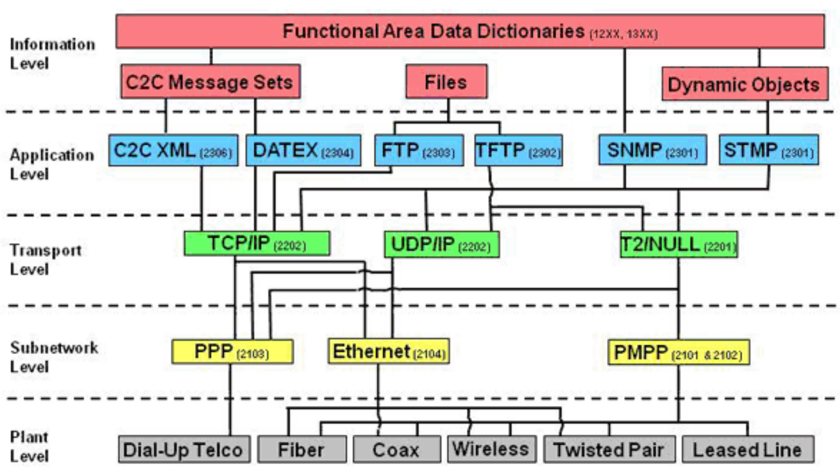


Figure 3. NTCIP Framework[3]

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[1] Clear Roads. *Preliminary Clear Roads Universal In-Cab Performance Specifications and Communications Protocol*, http://clearroads.org/wp-content/uploads/dlm_uploads/Clear-Roads-Universal-In-Cab-Communications-Protocol-141016.pdf, 2014.

[2] National Electrical Manufacturers Association. *NTCIP Framework: Protocol Chart.* http://www.ntcip.org/library/protocols/. Accessed Oct 7, 2015.

[3] National Electrical Manufacturers Association. *NTCIP Framework.* http://www.ntcip.org/library/protocols/NTCIPFrameworkFor9001a.gif. Accessed Oct 7, 2015.

Vendor Protocols

Various vendors already sometimes use proprietary protocols to meet specific needs of their clients. For example, some AVL equipment transmits spreader controller information to a point location.

As of 2011, the following vendors AVL systems were used in the states shown[4]:

- IWAPI Weather Mgmt Data Collection - CO,WY, VA, ID (4)
- InterFleet - OH, MO, KY,(3)
- Location Technologies - IA, WA (2)
- Force America/Precise MRM - WA, WY (2)
- AmeriTrak's AT500, AT300 - NY, MN (2)
- Network Fleet - VA, NM (2)

Force America and their subsidiary Precise MRM use a protocol that tracks 37 separate parameters from their 5100ex, 5100 & 6100 spreader controllers including spreader information (material types, spread rates, gate settings) and environmental conditions such as road and air temperature[5].

As part of FHWA's Integrated Mobile Observation program, Minnesota's Deployment vendor AmeriTrak Fleet Solutions, LLC (AmeriTrak) developed a "Message Syntax Summary and Data Dictionary"[6]. This document includes both the general message syntax as well as headers (data "tags" that define the parameter type) and data formats for transmitting various sensor information collected on a snow plow. This document was published in 2013 and additional development has occurred in the interim to add more parameters. In particular, the 2013 document includes parameters received from:

- Dickey-John Control Point systems
- Force America controllers
- Driver input from a Mobile Data Terminal (MDT)
- Vaisala's temperature and humidity sensor
- CAN bus information from the OBD2 port

Among these parameters are hundreds of sensor and vehicle parameters including location, plow status, pavement temperature, fuel level, and current lane.

Another example is Cirus Controls' protocol that integrates "GPS vehicle location, road and air temperature, hydraulic pressure, vehicle speed, plow and hoist position, and spreader application

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4 Venner, M., *GPS/AVL Technologies in Use at State DOTs,*. Presentation at AASHTO Maintenance Meeting, July 19, 2011.

5 Force America, *5100ex, 5100 & 61000 Event Data Sheet*, 2015.

6 Edelstien, J. *Message Syntax Summary and Data Dictionary*. https://its-rde.net/data/downloadDEMetaStream?deMetaDownloadId=10082, Accessed Oct. 7, 2015.

rates".[7] This protocol is not currently published so the complete listing of information types is not available.

Store and Forward

Some implementations of communication systems have intermittent communications connections. For example, an agency might experience cellular data dead zones or they may use a system designed such that the communications are placed strategically—for example Wi-Fi hotspots in the garage. In those cases, it is important that there is a "store and forward" capability built into the communication system. This allows data to be passed to the point location, even if the entire data payload cannot be transmitted as it is collected or as a communications access point is reached.

Connected Vehicle

In recent years, FHWA has been promoting Connected Vehicle (CV) technology through its Intelligent Transportation Systems Joint Program.

One primary communication method for Connected Vehicles is Dedicated Short Range Communication (DSRC). This method is advantageous because it uses designated licensed bandwidth (5.9 GHz), has low acquisition/latency time, and has high reliability. However, communication range is limited to several hundred meters. Thus, a mobile vehicle would need to send its data payload as it comes in proximity with a data receiver. These access points could be located in strategic locations throughout the jurisdiction or could be limited to the garage. DSRC is designed around high bandwidth (greater than 20 megabits per second) and low latency communication with high data payloads.

Data Used in Winter Road Maintenance

United States Agencies

In 2006, the Western Transportation Institute completed NCHRP Project 20-7(200) Vehicle-Based Technologies for Winter Maintenance: The State of the Practice"[8]. In that year, the focus was generally limited to vehicle location and environmental conditions including temperature and road surface salinity. In the last nine years, sensor technology has progressed and the interest in gaining additional information from snow plows has increased significantly.

Automatic Vehicle Location (AVL) technology has been widely adopted in recent years by DOTs, counties, and cities to improve their winter maintenance operations. The technology was initially explored in the late 1990's by several agencies, notably the Virginia DOT's NOVA district, the

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[7] Cirus Controls, *Advanced Vehicle Sensors for Data Gathering*, http://www.ciruscontrols.com/wp-content/uploads/2014/02/CirusControls_Sensors_SellSheet_0711.pdf. Accessed Oct. 7, 2015.

[8] Shi, X. et al, *Vehicle-Based Technologies for Winter Maintenance: The State of the Practice*, 2006.

Minnesota DOT's Safety with Automated Intelligent Locator (SAIL 1) program, and the Southeastern Michigan Snow and Ice Management (SEMSIM) project.

Common uses for today's AVL technology in winter maintenance vehicles include vehicle locating and recording spreader information. Some agencies have chosen to make their snowplow information publicly available on GIS-based websites, such as the Iowa DOT's ESRI map portal[9] and Wayne County's Compass website.[10] Some DOT's also transmit blade position, road and air conditions, engine and fuel information, and photos of roadway conditions through the AVL system[11] [12].

The hardware used by agencies widely varies as there are many different AVL and spreader controller vendors. The Iowa DOT[13] and Pennsylvania DOT[14] use cellphones in winter maintenance vehicles to gather and transmit data. The cellphone apps take periodic photos from the driver cabin of the roadway and have the ability to collect location data through phone applications.

A 2011 Virginia DOT survey[15] found that DOT's commonly use AVL/GPS systems for:

- Snow Control Efficiency
- Vehicle Routing Efficiency
- Vehicle Tracking in Remote Areas
- Recording Vehicle Usage History
- Obtaining Real-time Road Conditions
- Measuring Bed Weight and Material Usage
- Capturing Roadway Images

The survey showed DOTs would like to have the ability to collect:

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9 Iowa Department of Transportation. *Interactive Map Portal.* http://iowadot.maps.arcgis.com/home/. Accessed Oct. 7, 2015.

10 Wayne County, Michigan. *Compass*, http://compass.waynecounty.com/. Accessed Oct. 7, 2015.

11 Neill, M., G2: AVL/GPS Use for Winter Maintenance.
http://www.nritsconference.org/downloads/Presentations14/Neill_G2.pdf.

12 Iowa Department of Transportation, Snow Plow Tracking GIS-T 2015, https://prezi.com/_-2xuycyso4q/snow-plow-tracking-gis-t-2015/

13 Iowa Department of Transportation, Snow Plow Tracking from Start to Finish, http://www.gis-t.org/files/G03Rk.pdf

14 Pennsylvania Department of Transportation, Road Condition Reporting,
http://www.dot7.state.pa.us/BPR_PDF_FILES/Documents/Research/Complete%20Projects/Operations/Road_Condition_Reporting_Final_Report.pdf

15 AASHTO, GPS/AVL Technologies in Use at State DOTs,
http://transportation.ky.gov/Maintenance/Documents/AASHTO%20Presentations/General/AVL%20GPS/GPS%20AVL%20Technologies%20in%20Use%20at%20State%20DOTs.pptx

- Atmospheric Pressure
- Wiper Status
- Headlight Status
- Sun Sensor
- Accelerometer
- Impact Sensor
- Steering Angle
- Anti-lock Braking System Status
- Vehicle Error Codes
- Idle Time
- Video Streaming – in front roadway conditions, spreader material outflow, and behind for backing up safety

As of 2015, the Idaho Transportation Department has installed communications hardware for plows to be able to transmit plow data at environmental sensor station (ESS) sites. This allows them to compare the mobile data to the conditions reported by the ESS site.[16]

The Wyoming Department of Transportation has developed a "Road Condition Reporting App" that allows the driver to easily input data about road conditions during plowing operations[17]. This project represents a new type of data that has recently become available with the proliferation of consumer grade mobile computing devices. A screenshot from the app is shown in Figure 4.

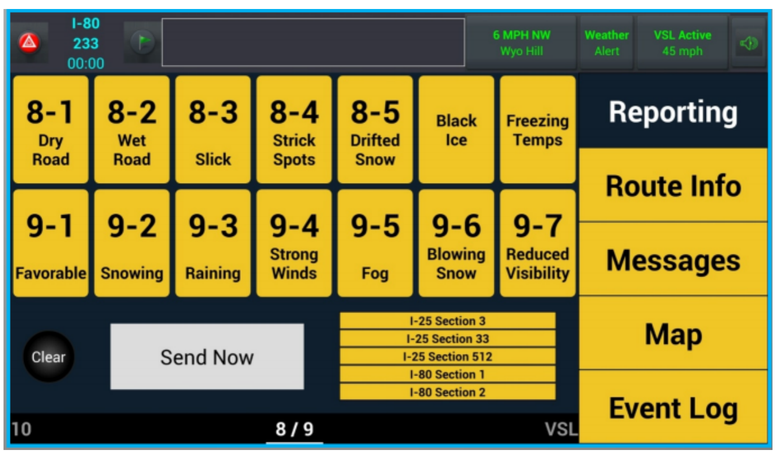

Figure 4. Wyoming DOT Mobile Data App.

Researchers at Global Science & Technology have implemented a Mobile Platform Environmental Data (MoPED) sensing system to be used on commercial fleets and uses the J 1939 including

[16] http://itd.idaho.gov/transporter/2015/041715_Trans/041715_D2CirusControllers.html

[17] Ragan, Ali, Road Condition Reporting App, Presentation at the 2015 National Winter Maintenance Peer Exchange, https://docs.google.com/viewer?a=v&pid=sites&srcid=ZGVmYXVsdGRvbWFpbnwyMDE1cGVlcmV4Y2hhbmdlfGd4OjQ5NTVkN2QxNmNhMTljMWQ

various environmental and vehicle data parameters. The sample protocol syntax that is presented in this report features numbered ID tags that correlate with defined parameters. [18]

The National Center for Atmospheric Research developed a process to ingest mobile data from the controller area network (CAN bus) and other mobile weather sensors called the vehicle data translator (VDT).[19] The CAN bus is a controller area network that allows on-vehicle microprocessors to communicate with each other without a dedicated controller.

International Agencies

Publications about road maintenance in non-North American countries were more difficult to find. Web searches and a review of papers from the last two International Symposia on Snow Removal and Ice Control Technology (2008 and 2012) provided some insight into international approaches.

Denmark uses the VINTERMAN centralized system to manage all aspects of winter weather maintenance including tracking snow plow locations and spreader information. This system uses a protocol called the Standard for Communication Between VINTERMAN and the Road Clearing Equipment. This protocol initially only managed information reported from the vehicle, but was also expanded to GPS-controlled spreading. This standard is based on the German DAU-protocol for mobile data collection. [20]

Many other countries have made preliminary steps into mobile data acquisition from private vehicles. Korean researchers implemented a system for interfacing with automobile safety sensors to determine problematic road conditions.[21] Similarly, Swedish researchers implemented a Slippery Road Information System that uses data from standard safety systems in vehicles to detect slippery roads, such as electronic stability and antilock braking. This system incorporated extra communications equipment and suggested to integrate this technology into vehicle communication systems as they become more prevalent.[22] As of 2007, Finland did not include data from mobile sources as part of its road weather program. At that time, efforts were focused on transmitting ESS data to the mobile vehicles.

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[18] Bell, B. *National Mobile Environmental Observation Network Increasing Insight to Road Weather and Surface Conditions*. Global Science & Technology.

[19] Drobot, S. et al. *Tomorrow's Forecast Informed Drivers*. National Center for Atmospheric Research, 2012.

[20] Knudsen, F. *Quality Improvement of Winter Service in Denmark*. Danish Road Directorate, 2012.

[21] Diagnosing Hazardous Road Surface Conditions Through Probe Vehicle as Mobile Sensing Platform JINHWAN JANG NAMCHUL BAIK Korea Institute of Construction Technology

[22] Bogren, J. *Intelligent Transportation Systems and Support System for Winter Road Maintenance,* Göteborg University, Sweden. 2012.

A specification for an AVL protocol that includes vehicle and position information was found from the Swedish Transport Administration.[23] However, this document is available only in Swedish and only cursory information could be understood from it. The specification contains a data structure with XML tags and the relevant syntax. Most of the syntax is presented in English. This protocol did not contain some of the more sophisticated elements that were found in US-based protocols.

[23] Trafikverket (Sweden). *GPS Positionerade fordon – Basunderhåll Väg*, http://www.trafikverket.se/contentassets/dcd580c5333340108b86b4b01f020ede/gps_positionerade_fordon_bas_underh_vag_v2_2_trv2014_49600.pdf, Accessed Oct. 7, 2015.

Future/Other Technologies

Work currently being done by public transit agencies provides a source of insight since these agencies are proactive about implementing new technologies that benefit their riders, drivers, and management. The transit industry uses a wide variety of technologies to improve operations. The list at the end of this section summarizes various technologies including many that already integrate data transmission to the transit office/database. Other items are technologies that are typically locally controlled, but could be managed from the office. Examination of the transit industry's use of vehicle systems and data management tools can provide insight into future applications for maintenance vehicles.

Transit service may be broken into fixed route and on-demand (paratransit) services and each method employs on technologies that match the service's operational needs. Fixed route services are scheduled bus and rail services and typically benefit from giving users real time information about route and trip status. Paratransit uses several technologies to schedule trips for passengers on demand. Because the route the vehicle follows is variable, on-vehicle technologies including map and route may be displayed to the driver.

Other technologies are useful to various service types. The Ohio DOT analyzed transit technologies[24] and found that the following technologies were the most desired among their stakeholders: automatic vehicle location/global positioning systems (AVL/GPS), automated passenger counters, scheduling software, electronic fare collection – real time information – online trip planners (e.g. Google Transit).

Transit signal priority is gaining momentum among transit providers because it improves transit operation by giving "transit vehicles a little extra green time or a little less red time at traffic signals to reduce the time they are slowed down by traffic signals."[25]

Clever Devices[26], offers the following products: computer-aided dispatch, real-time bus arrival technologies, vehicle health monitoring, bus stop announcements, turn warning (audible alert to pedestrians), infotainment, automatic passenger counting, traffic signal priority, hands-free digital microphone, geofencing, and paratransit applications.

The Bus 2.0 project deployed new bus technologies for assisting drivers in a test environment in 2011. This project implemented DGPS-based Lane Keeping, Forward Collision Awareness, and Side Collision Awareness. The system gave the driver feedback "graphically, through a Head Up Display

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24 Ohio Department of Transportation. *Initiative: Transit Technology Needs*. http://www.dot.state.oh.us/Divisions/Planning/Transit/TransitNeedsStudy/Documents/InitiativePaper-TransitTechnologyNeeds.pdf. Accessed Oct 7, 2015.

25 Federal Transit Agency. *Transit Signal Priority (TSP): A Planning and Implementation Handbook*. http://www.fta.dot.gov/documents/TSPHandbook10-20-05.pdf. Accessed Oct 7, 2015.

26 Clever Devices. *Product Overview*. http://www.cleverdevices.com/products-overview.htm. Accessed Oct 7, 2015.

(HUD) which provides a driver a virtual view out the windshield when environmental conditions limit visibility, haptically, through a torque-actuated steering wheel which provides a restorative torque on the steering wheel in the event of lane drift, and tactically, through a seat equipped with actuators which vibrate on the side of the seat to which the lane is being departed." [27]

A summary of the transit technologies found during the literature search is categorized and listed below.

Transit Operations Technologies

- Reservation system for paratransit, typically includes call centers or websites to take reservations, a centrally controlled routing system for determining routing
- AVL including route information
- Electronic fare collection
- Automatic passenger counting
- Transit signal priority, including operating gates or bus-only bypass
- Automated voice annunciation
- Radio to dispatch
- Automated docking for bus rapid transit that allows the bus to stop within a few inches of the platform to allow for wheelchair access
- Diagnostics including maintenance info and fuel level

Customer Information Technologies

- Dynamic signs that update in real time to display information such as the next bus arrival time
- Display inside vehicle displaying customer information including stop information
- Screen outside vehicle displaying route information
- Mobile apps
- Customer Wi-Fi

Safety Technologies

- Silent alarm that driver can trigger when safety is threatened
- Video cameras
- Microphones (for silent alarm)
- Pedestrian detection and alerts
- Driver assist technologies
- Collision warning systems

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[27] Shankwitz, C. *Bus 2.0, Driving Advanced Technology into the Future, DGPS-Based Driver Assistive Systems: Helping Drivers Better Utilize Bus-Only Shoulders.* http://www.bus2.me.umn.edu/background.html. Accessed October 7, 2015.

Although many of the technologies mentioned in this section are specific to transit, some may have potential future applications for supporting maintenance efforts or comparable systems may be implemented that are tailored for maintenance specific applications.

Agency Survey Results

In spring 2016, a survey was conducted of agencies that perform winter maintenance. The list of survey respondents was gathered from contact lists from Clear Roads and Aurora members with a goal of one survey response per state as well as international and local agency responses.

The summarized responses from the following states' departments of transportation are provided.

- Idaho
- Illinois
- Kansas
- Maine
- Michigan
- Missouri
- Nebraska
- North Dakota
- Ohio
- Oregon
- South Dakota
- Utah
- Vermont
- Washington
- Wisconsin (compiled responses from 21 Wisconsin counties)
- Wyoming

The following international and local agencies provided responses.

- Region of Waterloo, Ontario, Canada
- City of Brampton, Ontario, Canada
- Ontario Ministry of Transportation
- City of Minneapolis, Minnesota

Each agency listed is equally represented in the results analysis.

Special note about the Wisconsin data: Wisconsin counties perform winter maintenance rather than the Wisconsin Department of Transportation. The responses from 21 Wisconsin counties were aggregated to represent the Wisconsin response. In general, these responses were consistent with each other, although a weighted average response was used where the response was not consistent.

Data Types for Winter Maintenance.

The survey captured the current use and needs for a data transmission protocol. The survey requested that users indicate whether their agency is using the data type and how important that data type is to the agency (very important, somewhat important, or not important).

To analyze the importance ratings, a scoring system was implemented to convert the importance ratings to "points":

- Very Important: 100 points

- Somewhat Important: 50 points
- Not Important: 0 points

The points were averaged to determine an "Importance Score" with generally unimportant data types scoring less than 40 and generally important data types scoring more than 60. This 0 to 100 point scale is useful for comparing what agencies think are important versus what data types they currently track.

The raw data tables are presented on the next pages and then analysis follows.

Vehicle Data Types	Percent Using	Importance Score
Vehicle Location	82%	94
Accelerometer (3-axis)	13%	27
Active Inputs (ignitions, vehicle lights, windshield wipers)	24%	35
Coolant Temperature	18%	35
Fuel Pressure	6%	21
Engine RPM	13%	29
Vehicle Speed	82%	76
Intake Air Temperature	6%	16
Idle Time	63%	69
Run Time Since Start	56%	49
Electronic Control Module (ECM) Vehicle Diagnostic Codes	24%	65
Fuel Level	6%	20
Barometric Pressure	0%	20
Ambient Air Temperature	38%	68
Engine Fuel Rate	6%	26
Throttle Position	0%	21
Traction Assist On/Off	0%	20
Lateral Acceleration	0%	15
Steering Angle	0%	15
Yaw	0%	21
Roll	0%	21
Brake Pedal On/Off	0%	20

Image/Video/Traffic Data Types	Percent Using	Importance Score
Dashcam or Other Still Images	12%	58
Video	0%	48
Radar Traffic Detection	12%	36

Spreader Data Types	Percent Using	Importance Score
Current Spreader Status (on/off)	75%	92
Current Granular Material and Type	65%	88
Current Liquid and Type	71%	88
Granular Material Usage - Set Spreading Rate	76%	93
Granular Material Usage - Actual Spreading Rate	76%	93
Liquid Material Usage - Set Spreading Rate	71%	88
Liquid Material Usage - Actual Spreading Rate	75%	92
Pre-wet Tank Level	0%	52
Gate Setting	31%	77
Storm Material Total (Granular)	81%	96
Storm Material Total (liquid)	75%	95
Spinner Dial Setting	31%	76
Pre-wet Material Setting	63%	90
Dust Control Settings	6%	23
Duration in Automatic/Blast Modes	44%	73

Environmental Data Types	Percent Using	Importance Score
Air Temperature	75%	80
Pavement Temperature	76%	90
Precipitation Sensor (yes/no)	13%	71
Relative Humidity	19%	64
Sun Sensor (percent intensity)	0%	55
Surface Grip	6%	79

Operator Interface/Controller Data Types	Percent Using	Importance Score
Current Lane	7%	51
Plow Status (up/down)	71%	79
Road Condition	38%	81
Weather Condition	38%	77
"Bare Lane" Declaration (yes/no)	0%	61
Controller Status Codes	31%	67

Data Types Analysis Scoring

To determine which data types are essential to the "Plug and Play" protocol, it is useful to sort the data types according to their "Importance Score." The following table is a ranked list of data types. The list is further categorized by the scoring with three color-coded levels of Importance Score. Green (61-100) importance scores must be included if feasible in a Plug-and-Play protocol. Yellow (41-60) importance score indicates parameters that should be included to encourage widespread adoption, but may not be necessary. Red importance scores (0-40) indicate that these parameters are useful if it is desirable to have a comprehensive protocol. For example, even data types that scored only around 25 indicate that about half of respondents found them "somewhat important."

Data types that score highly should be considered for mandatory inclusion in appropriate plug-and-play standards while lower scoring data types may be considered for optional inclusion.

Data Type	Percent Using	Importance Score
Storm Material Total (Granular)	81%	96
Storm Material Total (liquid)	75%	95
Vehicle Location	82%	94
Granular Material Usage - Set Spreading Rate	76%	93
Granular Material Usage - Actual Spreading Rate	76%	93
Current Spreader Status (on/off)	75%	92
Liquid Material Usage - Actual Spreading Rate	75%	92
Pavement Temperature	76%	90
Pre-wet Material Setting	63%	90
Current Granular Material and Type	65%	88
Current Liquid and Type	71%	88
Liquid Material Usage - Set Spreading Rate	71%	88
Road Condition	38%	81
Air Temperature	75%	80
Surface Grip	6%	79
Plow Status (up/down)	71%	79
Gate Setting	31%	77

Data Type	Percent Using	Importance Score
Weather Condition	38%	77
Spinner Dial Setting	31%	76
Vehicle Speed	82%	76
Duration in Automatic/Blast Modes	44%	73
Precipitation Sensor (yes/no)	13%	71
Idle Time	63%	69
Ambient Air Temperature	38%	68
Controller Status Codes	31%	67
Electronic Control Module (ECM) Vehicle Diagnostic Codes	24%	65
Relative Humidity	19%	64
"Bare Lane" Declaration (yes/no)	0%	61
Dashcam or Other Still Images	12%	58
Sun Sensor (percent intensity)	0%	55
Pre-wet Tank Level	0%	52
Current Lane	7%	51
Run Time Since Start	56%	49
Video	0%	48

Continued on next page

Data Type	Percent Using	Importance Score
Radar Traffic Detection	12%	36
Coolant Temperature	18%	35
Active Inputs (ignitions, vehicle lights, windshield wipers)	24%	35
Engine RPM	13%	29
Accelerometer (3-axis)	13%	27
Engine Fuel Rate	6%	26
Dust Control Settings	6%	23
Fuel Pressure	6%	21
Throttle Position	0%	21

Data Type	Percent Using	Importance Score
Yaw	0%	21
Roll	0%	21
Fuel Level	6%	20
Barometric Pressure	0%	20
Traction Assist On/Off	0%	20
Brake Pedal On/Off	0%	20
Intake Air Temperature	6%	16
Lateral Acceleration	0%	15
Steering Angle	0%	15

Gap Analysis

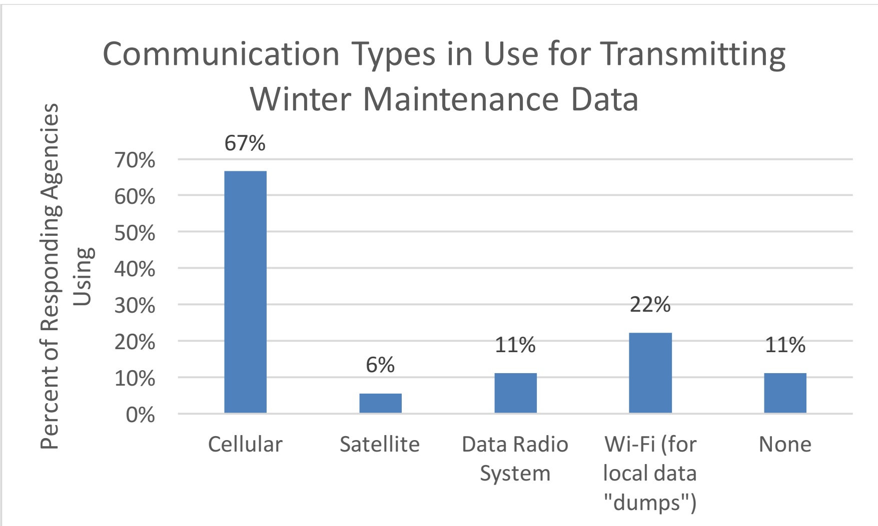
There is reasonably good correlation between the data types that are currently in use and those that the surveyed agencies find important. However, there are several data types where the "Percent Using" is more than 20 percentage points less than the "Importance Score." The following list is sorted with respect to the greatest use/importance gap (i.e. Importance Score minus Percent Using). This is an indicator of data types that may be expected to become more prevalent in the coming years assuming the industry makes devices for capturing these data widely available.

Data Type	Percent Using	Importance Score
Surface Grip	6%	79
"Bare Lane" Declaration (yes/no)	0%	61
Precipitation Sensor (yes/no)	13%	71
Sun Sensor (percent intensity)	0%	55
Pre-wet Tank Level	0%	52
Video	0%	48
Dashcam or Other Still Images	12%	58
Gate Setting	31%	77
Spinner Dial Setting	31%	76
Relative Humidity	19%	64
Current Lane	7%	51
Road Condition	38%	81
Electronic Control Module (ECM) Vehicle Diagnostic Codes	24%	65
Weather Condition	38%	77
Controller Status Codes	31%	67
Ambient Air Temperature	38%	68

Communication Methods/Store and Forward

Communications Methods

The respondents were asked to indicate which communication types they currently use. The following chart shows that cellular communication systems are by far the most common. Note that respondents were encouraged to indicate all methods that they currently use (thus, the sum of all percentages is greater than 100 percent).



The results showed that even if an agency uses an alternative communication method to cellular, it usually does so **in addition** to cellular.

Store-and-Forward

Respondents indicated an overwhelmingly positive response to the store-and-forward concept. This underlines the need for systems to be able to store data when communications are not available.

All of the non-Wisconsin respondents that answered this question indicated that the system "must have" store-and-forward capabilities. The aggregated Wisconsin response had a slight preference for "must include," but respondents chose all preference options generally uniformly.

By far, the most common duration requested for store-and-forward was one day. This would be commensurate with a winter maintenance program wherein the vehicles return to a truck station on a daily basis where there is known connectivity. The next most common trend was that about 28 percent of agencies desired more than 14 days of store-and-forward capacity. This may indicate that the trucks are not able to communicate for a period of days due to equipment or communication backend issues. Other durations between these two extremes were uncommon (one for three days and one for four days).

Freight Industry Survey

In spring and summer 2016, a survey was conducted of freight companies to learn more about typical industry practices for communication between freight trucks and central office data systems. Although the survey was sent to over 20 companies, it was difficult to obtain survey responses. The four responses provided are intended to provide a sampling of responses, but may not be large enough to draw firm conclusions.

However, through the process of attempting to collect data, additional information was gleaned through personal contacts. One of the prominent vendors from the freight telematics industry provided an interview that revealed significant information about major freight carriers that did not respond to the survey. Although the results of this interview could not be directly translated into individual survey responses, this combined response represents large freight companies.

The freight industry has generally not adopted open Plug-and-Play systems and has instead preferred to use proprietary cloud-based network operation centers (NOCs) to receive data from trucks. These data are then used by the companies' freight managers within the proprietary system or downloaded to their own data management systems.

In general, the freight industry survey responses are in line with expected results. The vehicle data that is collected by the survey respondents generally aligns with the data that is available directly from the truck along with location data and some information about the driver and load. In general, the data appears to be "opportunistic" meaning that if it is easy to obtain the data directly from the truck CAN bus, it is captured.

It was learned that PeopleNet's platform and Qualcomm's Omnitracs platform are popular products and are used widely in the industry. Some large freight companies have proprietary systems for managing data as well. Freight companies are perhaps more able to shift between proprietary vendors than public agencies. An additional benefit of proprietary protocols is that they include the flexibility to add data types and methods without wide industry adoption. However, it has generally been considered to be in the public's interest to invest in open systems that encourage cooperation between vendors. This is needed because funding for such systems is sometimes unknown and takes years of procurement planning.

Based on the survey responses, the needs of the winter maintenance community appear to be more stringent than those of the freight industry. The winter maintenance industry is interested in collecting myriad data from on-vehicle sensors including significant environmental and pavement data along with operational data logging and management. Thus, solutions developed for the freight industry do not currently be able to meet the needs that were defined in the agency survey.

Recommended Data Types and Next Steps

The information learned through this project led to several recommendations and next steps that Clear Roads or similar industry groups can move forward to further the goals of the Plug-and-Play concept.

The following core data types and units were identified as being necessary based on the agency survey respondents' ratings.

Category	Data Type	Value	Unit
Environmental Parameters	Ambient Air Temperature	decimal	degrees F or C
	Bare Lane Declaration (yes/no)	boolean	on/off (1/0)
	Pavement Temperature	decimal	degrees F or C
	Relative Humidity	decimal	percent relative humidity
	Road Condition	integer	lookup code
	Surface Grip	decimal (convert from integer if necessary)	friction coefficient
	Weather Condition	integer	lookup code
Spreader/Plow/Materials	Controller Status Codes	text	lookup code
	Current Granular Material	integer	lookup code
	Current Liquid	integer	lookup code
	Current Spreader Status (on/off)	boolean	on/off (1/0)
	Duration in Automatic/Blast Modes	time (HH:MM:SS)	time
	Gate Setting	decimal	percent open
	Granular Material Usage - Actual Spreading Rate	decimal	mass/distance
	Granular Material Usage - Set Spreading Rate	decimal	mass/distance
	Liquid Material Usage - Set Spreading Rate	decimal	volume/distance
	Liquid Material Usage - Actual Spreading Rate	decimal	volume/distance
	Plow Status (up/down)	boolean	on/off (1/0)
	Precipitation Sensor (yes/no)	boolean	on/off (1/0)
	Pre-wet Material Setting	integer	volume/pound
	Spinner Dial Setting	integer	lookup code
	Storm Material Total (Granular)	decimal	mass
	Storm Material Total (liquid)	decimal	mass
Vehicle	Air Temperature (From Vehicle)	decimal	degrees F or C
	Electronic Control Module (ECM) Vehicle Diagnostic Codes	text	lookup code
	Idle Time	time (HH:MM:SS)	time
	Vehicle Location	Decimal (lat.), decimal (long.)	latitude and longitude
	Vehicle Speed	integer	mph or kph

Additionally, the following recommendations and next steps were determined by the project team:

- Develop a family of standards that serves the needs of the winter maintenance community. Work with established industry protocols to ensure that the important winter maintenance parameters are included to an appropriate extent.
    - For example, NTCIP 1204 includes several parameters related to environmental factors and location, but does not have some data types were determined to be necessary for the Plug-and-Play concept. However, even if NTCIP were to incorporate these data types, it could not solve all issues in this topic area. For example, NTCIP does not support CAN bus or MDSS.
    - Other standards include MDSS, J2735 and J2945/x (Dedicated Short Range Communications). J2735 is largely complete as of 2016, but it does not include performance requirements.
- Transportation agencies should work with FHWA who can influence automotive industry groups to encourage them to go through the systems engineering process including requirements definition and to make sure the road/weather parameters are not overlooked.
- Transportation agencies should work together to develop procurement documentation that could include consistent protocol standards. The vendor industry can shift to meet standards/protocols that are written into procurement documentation. Boilerplate procurement language can facilitate the transition to Plug-and-Play standards.
- Winter maintenance stakeholders within agencies should get buy-in from agency IT departments to mitigate procurement and deployment issues.

In order to foster the implementation of such Plug-and-Play standards, Clear Roads should maintain a list of protocols that are considered Plug-and-Play and what data associated data types are targeted for those standards.

Conclusion

The Plug-and-Play Initiative: Phase 2 project provided information that winter maintenance agencies can use to develop a Plug-and-Play family of standards. Rather than a single, comprehensive, and fixed protocol, it is recommended to incorporate the data types into relevant existing standards, such as MDSS, NTCIP, and Connected Vehicle protocols. By getting involved with these standards, the winter maintenance data types can be "mainstreamed" into applications and foster improved interoperability.

The winter maintenance industry generally uses proprietary protocols. This means that systems from different vendors generally do not interoperate. However, this proprietary nature allows them to add functionality at will because full industry adoption is not required. As features become mainstream, it is recommended to incorporate these features into the open family of Plug-and-Play protocols. It may be necessary or prudent to allow these protocols to exist in parallel with the open standards.

Agencies can influence the industry through their purchasing decisions. By writing procurement documentation that reflects the desired to incorporate open standards, they can encourage vendors to adopt these standards, even if they run in parallel with the proprietary standards.

In summary, several independent and interrelated steps are needed for the winter maintenance industry to adopt Plug-and-Play standards. Thus, Clear Roads members must build buy-in for these concepts among many levels of agency, industry, and standards organizations personnel. This project lays the groundwork for what data types are most important as well as a vision for future data types that may gain importance in the coming years.

Appendix A – Freight Industry Responses

Freight Company Survey Response

1. **Does your company currently collect electronic data from trucks (i.e. location, type of load, time of delivery, etc)?** All responded that they do collect electronic data.
2. **How is data gathered?** All transmit data in real time.
3. **How does your system communicate to transfer data?** All use satellite. 3 of 4 use cellular. Schneider uses all four options presented in the survey (cellular, satellite, data radios, Wi-Fi). No company suggested other methods.
4. **If you know what software your system uses, please specify it below.** Responses were Qualcomm Omnitracs AS/400, proprietary system, and PeopleNet.
5. **Indicate which of the following vehicle data types your company currently collects (1/2):**
    a. Fuel Level **75% YES**
    b. Engine Fuel Rate **75% YES**
    c. Vehicle Location **100% YES**
    d. Active Inputs (ignitions, vehicle lights, windshield wipers) **75% YES**
    e. Coolant Temperature **25% YES**
    f. Fuel Pressure **25% YES**
    g. Engine RPM **75% YES**
    h. Vehicle Speed **100% YES**
    i. Intake Air Temperature **25% YES**
    j. Idle Time **100% YES**
6. **Indicate which of the following vehicle data types your company currently collects (2/2):**
    a. Automatic Log Books **75% YES**
    b. Route Optimization Software **100% YES**
    c. Devices to legally bypass weigh scales **50% YES**
    d. Environmental monitoring technologies (idle time/emissions) **75% YES**
    e. Diesel exhaust fluid levels **67% YES**
    f. Trailer-mounted GPS (not cab-mounted) **50% YES**
    g. Automated fuel system (for example, Fuelmaster) **75% YES**
    h. Run Time Since Start **100% YES**
    i. Electronic Control Module (ECM) **100% YES**
    j. Vehicle Diagnostic Codes **100% YES**
7. **Please tell us the most important pieces of information that you collect from trucks.**
    a. Vehicle Speed and Location (all respondents listed this, one was also interested in excess speed)
    b. Other aspects that each received one response: Hours available for driver, Idle time, ECM

Vendor-Reported Response

The following response summarizes several companies' usage of telematics in the freight industry based on the use of the vendor system.

1. **Does your company currently collect electronic data from trucks (i.e. location, type of load, time of delivery, etc)?** Yes, almost all major freight companies use telematics, but some small local carriers are not using telematics.
2. **How is data gathered?** Data is sent from the truck to a central point (for example, PeopleNet NOC). Data is transmitted from the field in real time.
3. **How does your system communicate to transfer data?** Almost all data is transmission is cellular. Satellite options are expensive and have lower bandwidth, but are used where cellular coverage is not available, such as mining in the Pacific Northwest. Additionally, some push-to-talk services use satellite.
4. **If you know what software your system uses, please specify it below.** Data collection devices are generally units with embedded operating systems (Linux/Windows) and dispatch systems. Those systems interface with the PeopleNet unit.
5. **Indicate which of the following vehicle data types your company currently collects (1/2):**
    a. Fuel Level **YES**
    b. Engine Fuel Rate **YES**
    c. Vehicle Location **YES**
    d. Active Inputs (ignitions, vehicle lights, windshield wipers) **YES, but not windshield wipers**
    e. Coolant Temperature **NO**
    f. Fuel Pressure **YES**
    g. Engine RPM **YES**
    h. Vehicle Speed **YES**
    i. Intake Air Temperature **YES**
    j. Idle Time **YES**
6. **Indicate which of the following vehicle data types your company currently collects (2/2):**
    a. Automatic Log Books **YES**
    b. Route Optimization Software **YES**
    c. Devices to legally bypass weigh scales **YES, including DriveWyze**
    d. Environmental monitoring technologies (idle time/emissions) **IDLE TIME-YES, EMISSIONS-NO**
    e. Diesel exhaust fluid levels **NO**
    f. Trailer-mounted GPS (not cab-mounted) **GENERALLY NO, although some systems tether the trailer GPS to the cab**
    g. Automated fuel system (for example, Fuelmaster) **NO, this is separate**
    h. Run Time Since Start **YES**
    i. Electronic Control Module (ECM) **YES**
    j. Vehicle Diagnostic Codes **YES**
7. **Please tell us the most important pieces of information that you collect from trucks**
    a. #1 Electronic driver logs
    b. #2 Current Location (Over-the-road companies)
    c. #2 Record of Stops (LTL companies)

CLEAR ROADS
research for winter highway maintenance

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