Aurora

working to advance road weather information systems technology

Mobile Weather and Road Condition Reporting

http://aurora-program.org

Aurora Project 2005-03

Final Report
May 2009

About Aurora

Aurora is an international program of collaborative research, development and deployment in the field of road and weather information systems (RWIS), serving the interests and needs of public agencies. The Aurora vision is to deploy RWIS to integrate state-of-the-art road and weather forecasting technologies with coordinated, multi-agency weather monitoring infrastructures. It is hoped this will facilitate advanced road condition and weather monitoring and forecasting capabilities for efficient highway maintenance, and the provision of real-time information to travelers.

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Final Report

Mobile Road Condition Sensors

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Executive Summary

This project demonstrated an automatic vehicle location (AVL) system with added data fields from either sensors or driver input to create a mobile reporting system for winter operations.

The project developed many solutions: a complete working AVL system that includes hardware, software to transfer data through the state police wireless network, and map-based reports of the data; an automatic data transfer into a Maintenance Decision Support System; a hotspot data transfer solution; and another hardware option using a smart phone device to collect and send data. The project also used sensors to determine field, weather, location, and chemical distribution amounts. These systems provide answers to an agency's desire to collect real-time data in maintenance operations.

Sensors were evaluated for friction and were deemed uneconomical for this project funding. Since the completion of the project, the Indiana Department of Transportation (INDOT) has purchased and is testing a Halliday Technologies RT3 friction device (about $25,000 at the time of purchase). This device produces friction values that are added to the data string for a maintenance decision support system (MDSS). Currently, the INDOT MDSS does not have the capability to display friction values.

Various sensors can be used in maintenance vehicles that are fairly economical to use. This project demonstrated that, by adding a few sensors and using driver judgment, road and weather conditions and maintenance activities can be reported in either real time or at various times through hot spots. Sensors that were added and tested through this project were a plow position sensor and infrared temperature sensors. The plow position sensor was placed in a hydraulic line and used backflow pressure to detect plow position. These are economical sensors (less than $1000) that provide important information during winter operations and for post storm evaluations and archival reasons.

Data came from various sources: sensors, a Muncie chemical controller, and driver input. Driver-required input was held to a minimum for safety reasons. The driver was required to input road and weather conditions through either an on-board laptop, tablet, or mobile computer. The sensor data was fed into the Muncie controller and combined with driver input. This data string from the various sources was then transferred to a server through the wireless network, where it was parsed and displayed on state geographic information system (GIS) maps.

The data was available to the MDSS through a file transfer protocol (FTP) connection. Meridian Environmental Technoloties would poll or collect the data at a set interval and display it to the MDSS. This MDSS connection is not difficult, but it requires cooperation and coordination between state information technology (IT) and Meridian.

The control unit, in this case Muncie, is the device where all data is collected. Any sensor has a limited number of ports for receiving data from remote sensors, so this is a limiting factor. In our case, there was one external port. One possible work-around is to work with the controller supplier to include sensors in their data string and be included with their controller.

Conclusions

- A statewide wireless network like the Indiana State Police is very unreliable and suffers from poor coverage areas and archaic data transfer technologies. State DOT agencies should perform a traffic and coverage analysis and explore security (firewall) issues before embarking on this option.
- Some remote sensors are very expensive and therefore not feasible to place on all winter vehicles. For example, the friction device could be placed on a patrol vehicle.
- Data transmission costs are a big component of any AVL system.
- The commercial AVL system mapping feature is typically poor quality and cannot utilize agency GIS maps.
- Collecting and transferring data through a PC/Smart Phone device may be an economical option.
- Hot spot data transfer is a secure reliable option but does not provide “real time” data.
- Investigate using the system for summer activities to make it more cost effective and provide a better return on the investment.
- The information can be used in the Condition Acquisition and Reporting System (CARS). An interface like that used in the MDSS will automate transferring the appropriate information.

Introduction

Decision support systems used in maintenance operations and a road condition system for the general public require various road condition data. Typically road condition data for maintenance decision support systems and for the traveling public require the manual recording and transferring of this information into these systems. Preferably this information would be collected electronically and formatted for use in these data systems.

Snow and Ice removal trucks provide an excellent option for collecting data in a mobile environment. There are a couple technical issues that need to be solved with this approach. One is as sensors are added to the mobile collector(snow plow vehicle)the collecting and assembling of the various data strings is an issue. The other is the transferring of this information to the maintenance decision support system and the traveling public road condition system. A current project at INDOT is utilizing the state-wide wireless data network, Safe-T. Another option that might be useful for INDOT and other DOT organizations is the use of Wireless Hotspots for collecting this data.

Problem Statement

Inefficient snow and ice removal efforts have serious consequences. Annually in the United States 1.5 million vehicle accidents occur resulting in 800,000 injuries, and 7000 fatalities. Also, 500 million hours of traffic delay result.

Directing, managing, and analyzing winter activities at DOT Agencies can be improved through the use of technologies. The current methodology of recording and entering this information occurs “after the fact.” The lack of current information can be detrimental. Also, documenting a DOT vehicle location and their activities is crucial in determining what time to make another application and what and how much chemical to apply. Due to lack of timely information a DOT can be improperly using vehicles and wasting chemicals.

AVL provides the capability to electronically record the location and activities of winter maintenance vehicles. This data can be transferred electronically and save time, improve data accuracy, and improve the feedback to INDOT managers that are responsible for making decisions on winter activities.

Other organizations that have used this technology report quantifiable improvements in their winter activities. These include improved reporting data, better utilization of equipment, and savings in fuel and chemical costs. A summary of AVL utilization by other organizations is found in the Appendix. Also, with data electronically imported into MDSS, management decisions can be better made in a timelier manner.

Sensors can provide data on road temperature, plow position, amount of chemicals spread, all which are valuable in making decisions in the snow and ice removal effort. Transferring this information into a information tool, like MDSS is another important function.

Research Objectives

The objective of this project is to develop an automated method of collecting road condition data and electronically transmitting the data to systems that require the data. It will also provide options for automating the transfer of data electronically into MDSS.

Work Plan

Scope of Work

- Evaluate the experience of other DOT organizations.
- Evaluate and select a wireless data transfer system.
- Setup and run a pilot at INDOT Subdistricts (Monticello and Columbus).
- Evaluate the hardware/software to check for compatibility to existing INDOT systems and equipment and automated data transfer to MDSS.
- Evaluate the feasibility and practicality of collecting weather data from snow plow operators.
- Evaluate the ability to report current road conditions.

First, a test of the system will be performed to check for usability of the system such as data transmission, vehicle monitoring, and data processing, as well as evaluating the hardware and software to be used.

Second, a pilot implementation at two INDOT Subdistricts will be conducted during the research period so as to evaluate the system's effect on road maintenance, efficiency of information regarding road conditions and management of snow removal fleet during two winter seasons.

Third, the research will then describe the pilot system implemented, and discuss the lessons learned from the implementation of the system.

Pilot Test Description

The pilot system consists of control software and AVL equipment and sensors including in-vehicle GPS receiver, post-processor, and a GPS board to be installed in a main control station. GIS software will also be needed for presentation of the post-processed data on a digitized local map.

Once the pilot system is installed, the system operation can be monitored 24 hours and the post-processed GPS data will be stored in a database for later review and evaluation.

Based on the test results, qualitative and quantitative analyses will be performed considering associated costs spent during the system development phase and potential quantifiable benefits from the developed system.

AVL Options

Two AVL options were considered and studied. Option 1 uses an AVL service provider where data is transferred via cellular service. There are numerous AVL service providers. Information was collected and a cost comparison done. This cost comparison is shown below in Tables 1-3. This system consists of proprietary software and a monthly service of $40 to $60 per vehicle.

Option 2 consists of using the Indiana SAFE-T wireless network to transfer data. The Indiana network is used by the State Police and a coverage map is shown in Figure 1. Coverage is available in the northern two thirds of the state. Installation is proceeding in the southern third of the state. Data is transferred through a 800mhz radio network with a transmission rate of 19.2 Kb that is managed by Motorola.

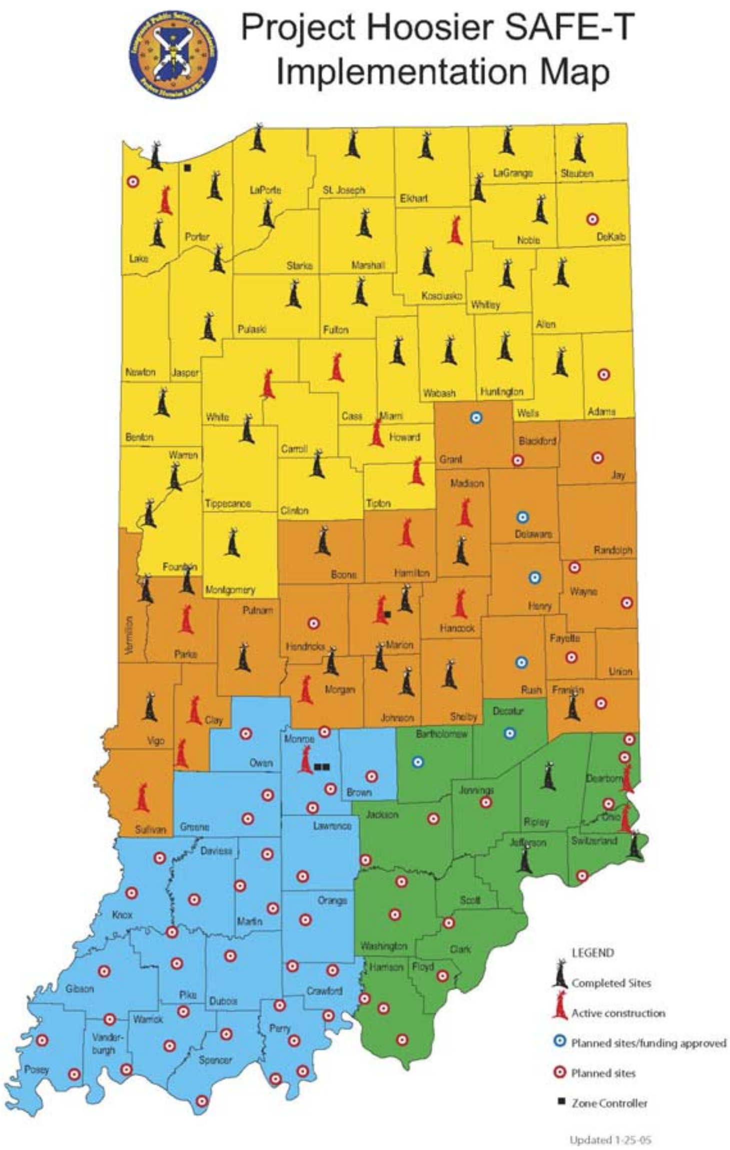


Figure 1 - SAFE-T Network

INDOT has approximately 1100 vehicles that participate in winter operations. Motorola did a data traffic study with this number of vehicles and determined that the data network has sufficient capacity to support this application. All equipment and software would be owned by INDOT.

Cost Comparison (1,000 trucks for 5 years)

Options	Hardware	Parts	Model / Vendor	Cost per Part	Subtotal	Total Maximum Cost
Option 1	In-Vehicle Equipment	GPS receiver + Modem + Data Terminal	Multiple Vendors	$500.00 – $900.00 / vehicle	$3,400.00 – $4,500.00 per vehicle	$4,500,000.00[1]
	Service Fee		Multiple Vendors	$2,700.00 - $3,600.00 / 5 years / vehicle ($45.00 – $60.00 / month / vehicle)		
Option 2	In-Vehicle Equipment	GPS receiver	GPS 18 / Garmin	$130.00	$3355.00 per vehicle	$3,753,390.00[2]
		Radio Modem + Antenna	VRM 850 / Motorola	$1,900.00		
		Rugged Laptop	ML 850 / Motorola	$1,200.00		
		IP Setting Software	MCSW2 / Motorola	$125.00		
	Base Station		AVL server	$ 5,000	$398,390.00	
	Map-Based Control Software		PU/INDOT	$ 0		
	File Transfer Module		PDMC Application Software / Motorola	$393,390.00[3]		

Table 1 - AVL Options Cost Comparison

1. $4,500.00 x 1,000 trucks, assuming the service fee is not changing for 5 years
2. $3,355.00 x 1,000 trucks + AVL server ($5,000) + PDMC Application Software ($393,390.00)
3. See the following table for details

Motorola PDMC Application Software (1,000 trucks for 5 years)

Year	Qty	Description	Cost	Subtotal	Total
Year 1	1	Wireless File Transfer Server Module ($16,130)	$16,130		
	1,000	Wireless File Transfer Client Module ($260)	$260,000		
		Maintenance	Warranty		
Motorola PMDC Application Software Subtotal (Year 1)				$276,130.00	
Year 2		Maintenance (10% of Software Cost)	$27,613		
Year 3		Maintenance (10% of Software Cost plus 4% escalation)	$28,718		
Year 4		Maintenance (10% of Software Cost plus 4% escalation)	$29,867		
Year 5		Maintenance (10% of Software Cost plus 4% escalation)	$31,062		
Motorola PMDC Software Maintenance Subtotal (Year 2 – Year 5)				$117,260.00	
Motorola PMDC Application Software Total (5 Years)					**$393,390.00**

Table 2 - Premiere MDC Cost

Cost Comparison after Year 5 between Option 1 and Option 2

Year	Option 1		Option 2	
	Additional Cost	Total	Additional Cost	Total
Year 5		$4,500,000.00		**$3,753,390.00**
Year 6	+ $720,000[1]	$5,220,000.00	+ $32,304.00[2]	**$3,785,694.00**
Year 7	+ $720,000	$5,940,000.00	+ $33,596.00	**$3,819,290.00**
Year 8[3]	+ $720,000	**$6,660,000.00**	+ $34,914.00	$**3,854,204.00**

Table 3 - Cost Comparison 5-8 Years

1. Annual Service Fee = $720.00 / vehicle / year x 1,000 trucks = $720,000.00 for Year 6
2. Annual Software Maintenance Cost (10% of Software Cost plus 4% annual escalation) = $31,062.00 (Year 5) x 1.04 = $32,304.00 for Year 6
3. First year that Option 1 costs more than Option 3, assuming the service fee in Option 1 is not changing

Option 2 is considerably less expensive due to the monthly service charge required in Option 1.

INDOT AVL System

Since the cost differential between these options is significant option 2 was chosen. Figure 2 is a conceptual diagram of option 2.

The first winter test period, 2005-2006, experienced weather and system problems. With the weather, there were very few winter events at these two sub locations to test with. There were several system issues. One was driver interface. Inputting the login and password as well as wireless signal verification troubled the drivers. Also, there was a need to do spot treatments and cleanup activities that could not be reported. These modifications were made during the summer of 2006. Also, the system was expanded to three locations and added six more trucks for the 2006 – 2007 season. The new location is to be Laporte and the truck distribution is:

Laporte – 4
Monticello – 3
Columbus – 3

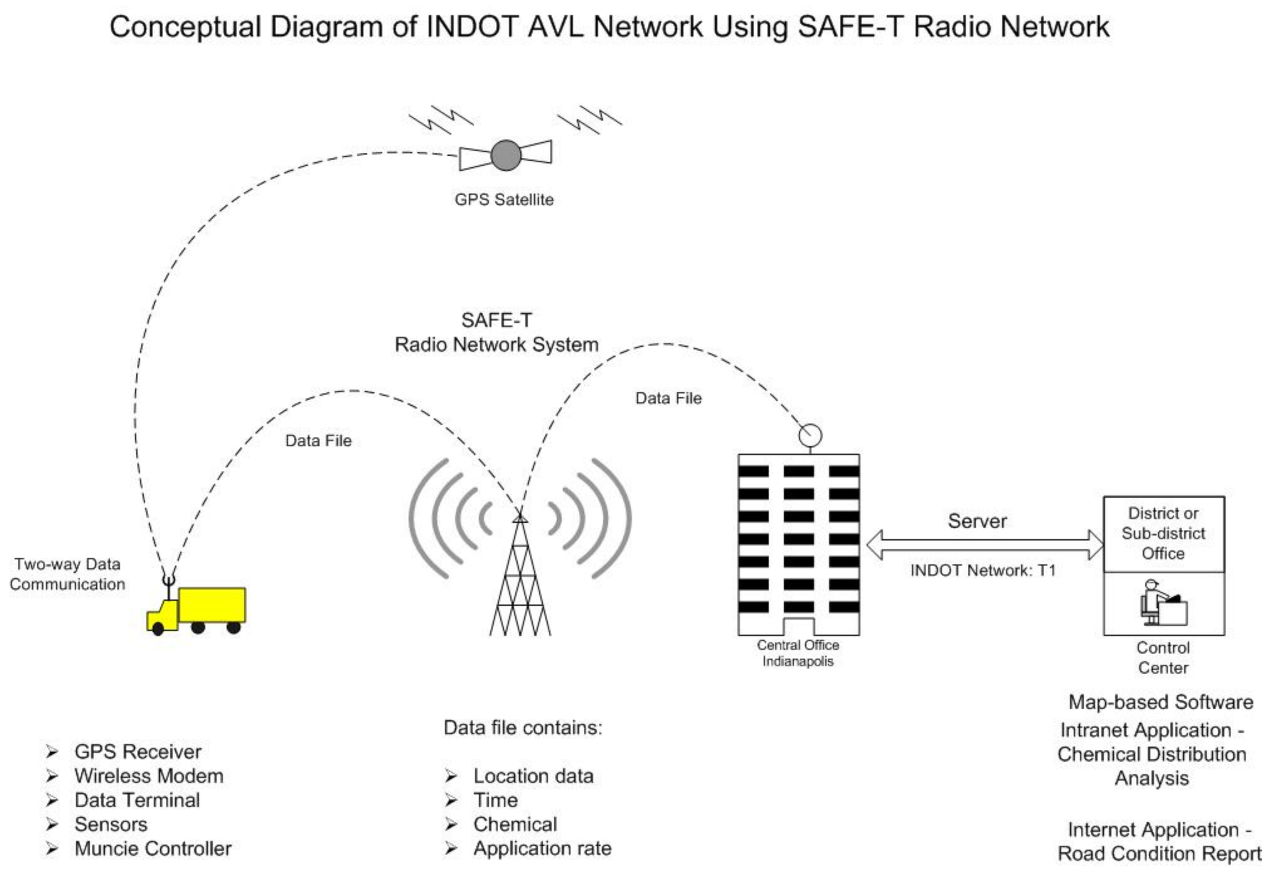


Figure 2 – INDOT System

A more detailed description and explanation of this system is described next.

Vehicle Hardware

A similar conceptual view of the in-vehicle hardware is shown below in Figure 3. There are four main hardware components in the trucks.

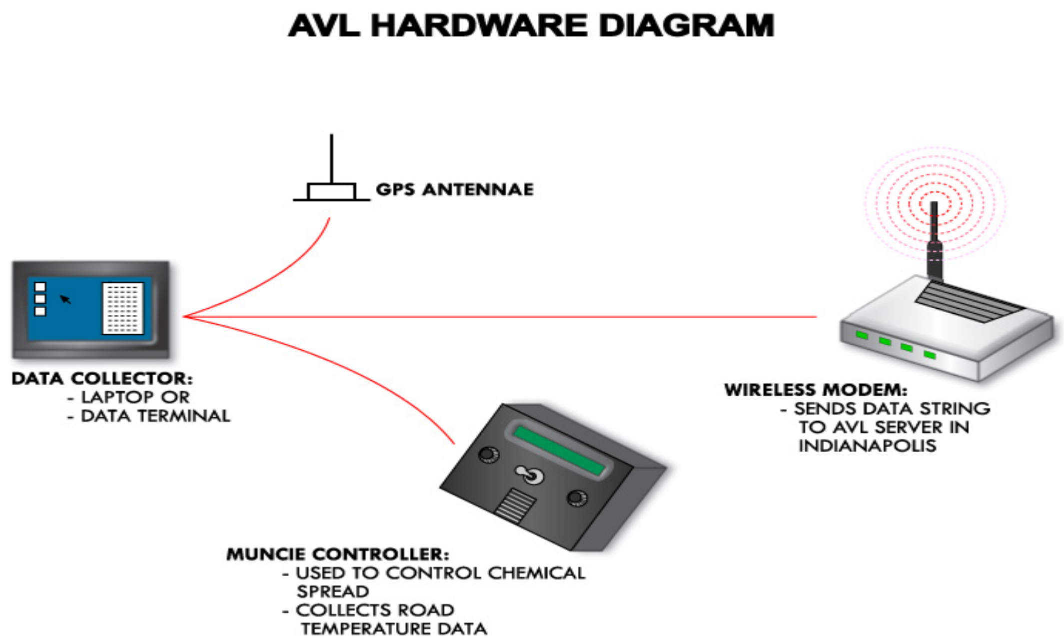


Figure 3 - Vehicle Hardware

GPS Antennae

Garmin GPS 18 receiver is a GPS OEM unit that receives location data from a satellite. This brand and model was chosen for its low cost and large operating temperature range. A comparison between GPS equipment is shown in the below table.

	Pharos	Garmin	Delorme
Model	iGPS-500	**GPS 18 OEM**	Earthmate LT-20
Price	$100.00	**$56.00**	$100.00
Sensitivity	-159 dBm	**-165 dBW minimum**	145 dBm
Channels	12 Channel all-in-view tracking	**12 Channel continuously tracks**	12 Channel
Acquisition time	Cold: 35s; Hot: 1s	**Cold: 45s; Hot: 15s**	Cold: 38s; Hot: 3s
WAAS	Yes	**Yes**	Yes
Dynamics (Max velocity)	972 knots (1800 km/h)	**999 knots**	1000 knots
USB	Yes	**Yes**	Yes
Operating temperature	-4 F to 167 F	**-22 F to 176 F**	-40 F to 185 F
Storage temperature	-40 F to 194 F	**-40 F to 176 F**	-67 F to 212 F

Table 4 – GPS Equipment Comparison

Chemical Distribution Controller

INDOT uses the Muncie Controller (MESP 402E) to control the distribution of chemicals from the winter vehicle. Through the course of the research project a temperature sensor and a plow position sensor were added to the vehicle. These sensor data are collected through the Muncie controller.

Wireless modem

Motorola modem (VRM 850, 800MHz 35W) transfers the data at regularly defined intervals from the truck to the AVL server in Indianapolis over the SAFE-T network. See Figure 2 conceptual diagram.

Data Collector

Three options for the in-vehicle data collector were tried and tested. A mini PC with touch screen monitor, a touch screen laptop, and an ultra mobile tablet PC were used as the computer data collection alternatives. The technical configuration for each device is in the Appendix.

Xenarc in-vehicle mini PC

Samsung Q1 ultra mobile tablet PC

Fujitsu B6210 touch screen laptop

The mounting options for these devices varied by location. The below two images show the mounting of a laptop and the mini PC screen.

Figure 4 – Laptop mounting

Figure 5 - Mini PC Screen Mounting

Prices for these three computer options is shown in the below table.

	Mini PC	Lifebook laptop	Ultra Mobile tablet
Computer	$1359	$1466.43	$982.38
GPS	$56	$56	$56
Modem, software license, preventive maintenance	$2285 +	$2285 +	$2285 +
Muncie Plow sensor	$60	$60	$60
Muncie Temperature sensor	$460	$460	$460
USB to serial cord	$34.99	$34.99 x2	$34.99 x2
USB Hub	N/A	$19.99	$19.99
Inverter	$79.97	$79.97	$79.97
Splitter	$7.99	$7.99	$7.99
Total	**$4342.95 +**	**$4505.36 +**	**$4021.31 +**

Table 5 - Computer Cost Comparison

Software was developed to interface the collector with the other three hardware devices: Muncie controller, GPS antennae, and Motorola modem. A description of this software follows.

Vehicle Software

Motorola MWCSII and Autoxfer

This software is a Motorola product and it transfers data over the SAFE-T network. The MWCSII software connects the modem in the client (truck) to the Safe-T network. The Autoxfer program is responsible for sending data to the server at defined intervals. The time interval that was used in our application is three minutes.

Garmin Spanner

The Garmin Spanner software writes the GPS data to a selected serial port. The data will then be collected through the Purdue Data Collecting software.

Purdue Data Collection Software

The Purdue Data Collecting Software was developed in Visual Basic 6. The program is activated at computer start-up. The first thing the program does is to start the Garmin Spanner program and the Motorola Autoxfer program. Both will run in the background. This software has a series of input screens for the driver, and combines the input with data from the Muncie controller and the GPS antennae. The combined data is sent every three minutes to the AVL server through the wireless network. The driver is required to input values for road and weather conditions and report road problem location as well as spot mode location.

Input Screens

There are two operation modes: (1) Chemical Spread and (2) Plowing Only. The Chemical Spread mode is used when the operation involves chemical spread with or without plowing. If no chemical spread occurs, no data is transferred. The Plowing Only mode is used when no chemicals are spread. The Muncie controller should be turned on in both modes.

Road Condition and Weather Condition

The driver has eight road and weather conditions to choose from:

Road Conditions

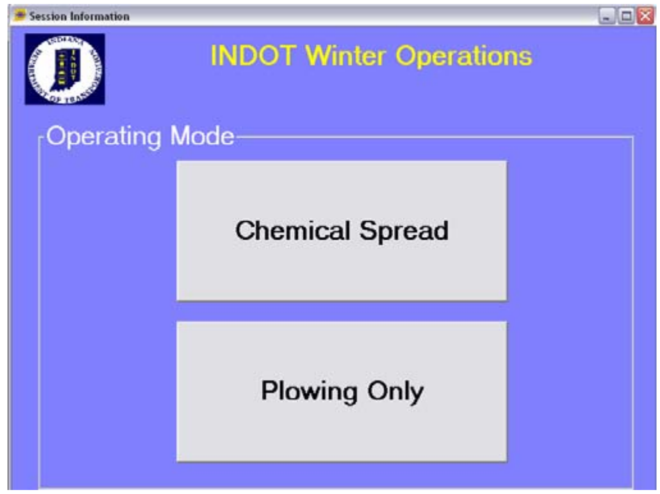
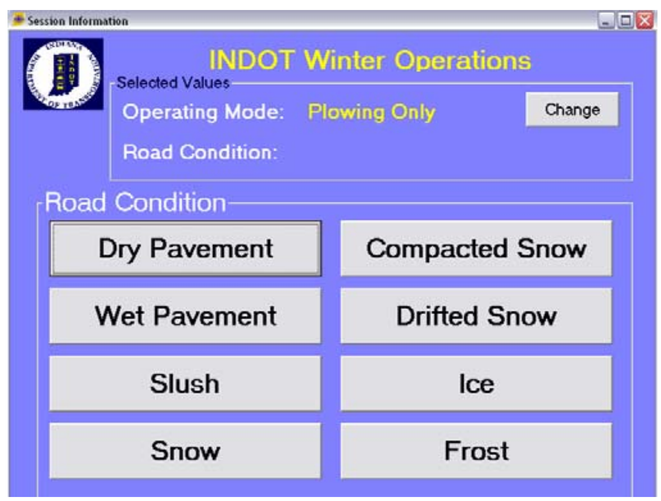
Dry Pavement	Compacted Snow
Wet Pavement	Drifted Snow
Slush	Ice
Snow	Frost

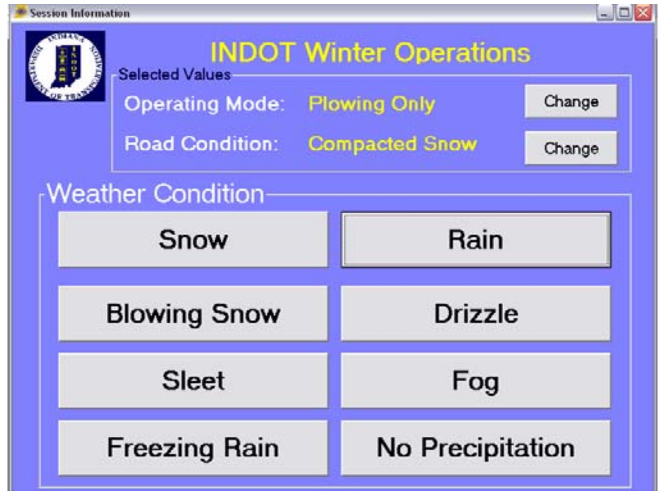
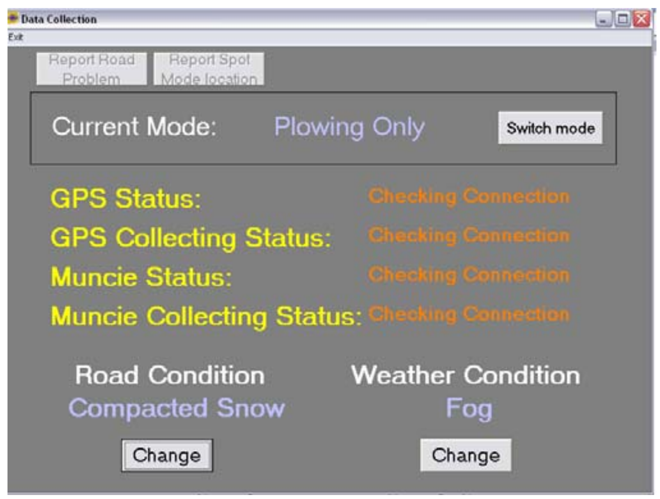
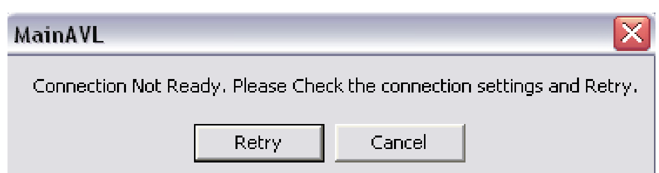
Weather Conditions

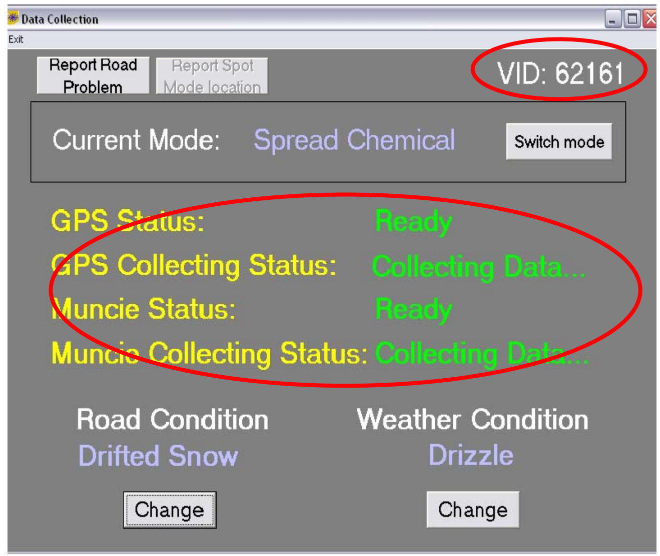
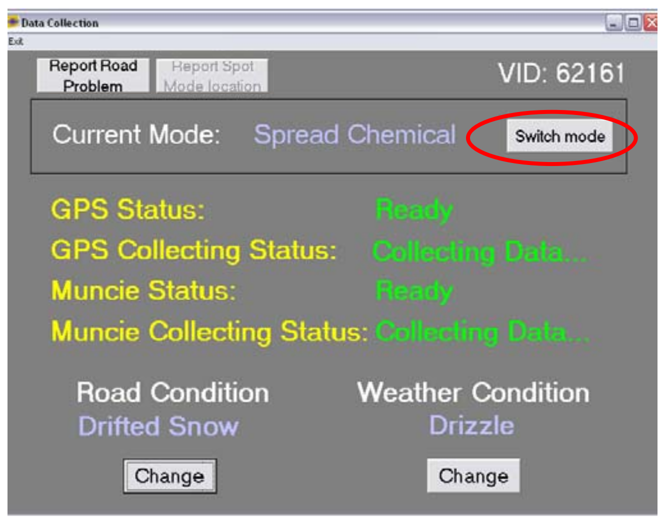
Snow	Rain
Blowing Snow	Drizzle
Sleet	Fog
Freezing Rain	No Precipitation

Screen Shots of the Purdue Data Collection Program

A detailed explanation on how the software works is shown in the following screen shots.

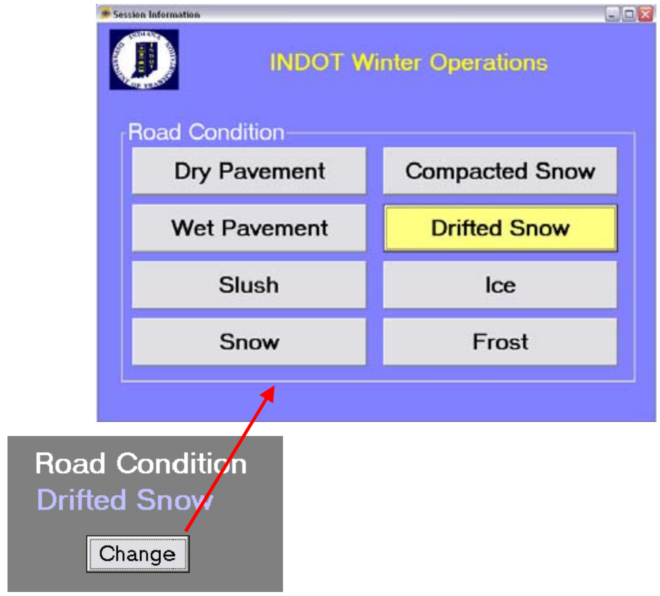
Description	Screenshot
Chemical Spread ◆ Spreading chemical with or without plowing. Plowing Only ◆ Plowing without spreading chemicals.	
Select a current Road Condition ◆ To change the selected Operating Mode, click Change button	

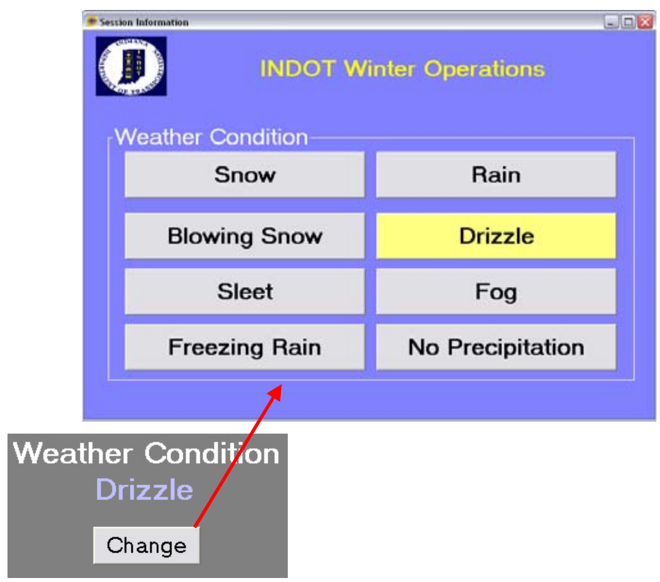
Select a current Weather Condition To change the selected values of Operating Mode or Road Condition, ◆ Click on the corresponding Change button next to the selected values	
The program will automatically check on the connections to GPS and Muncie.	
A pop-up appears if any of the connections are not ready. Check to see if the cables are connected.	

If both connections are good, ◆ The vehicle ID will appear on the top right corner. ◆ The program will automatically collect data from both devices. ◆ The flashing **Collecting Data…** will appear	
◆ Click on Switch mode button to switch between Spread Chemical and Plowing modes.	

To change a road or weather condition

- Click on the **Change** button.
- The original selection is highlighted.
- Select the new condition, and it will be highlighted.



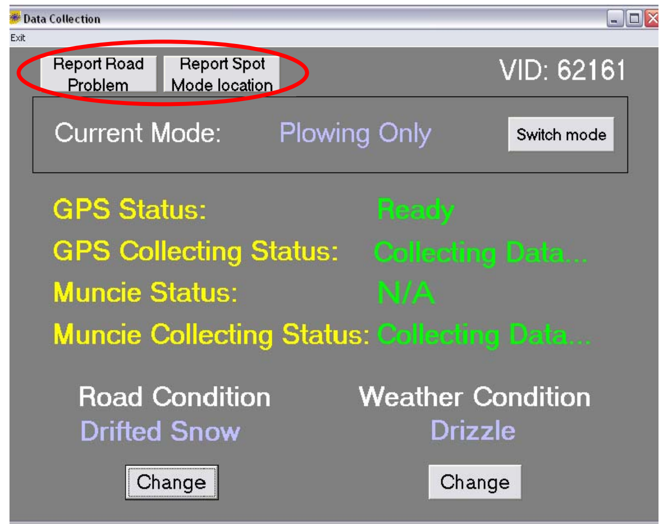


To report a Road Condition Problem at a particular location.

- Click on Report Road Problem button.

For Spot Chemical Application

- Click on Report Spot Mode location button.



Output data file

The below figure shows the data file structure that is transferred to the AVL server via wireless network. A description of these fields follows.

Field	Definition	
1	*Time (hhmmss)*	Time in format of hour, minute and second. Two digits each. (EST=GMT time minus 5 hours)
2	*X (m in UTM)*	X coordinate in UTM (Assumption: WGS84 Geodetic Coordinate)
3	*Y (m in UTM)*	Y coordinate in UTM (Assumption: WGS84 Geodetic Coordinate)
4	*UTM_Zone*	UTM zone (Assumption: WGS84 Geodetic Coordinate)
5	*Distance (m)*	Distance traveled in meter from start of the program
6	*Speed (mph)*	Speed in mile per hour
7	*Mode*	Muncie controller mode: N=Not Spreading, S=Spot, A=Auto & M=Manual
8	*MPH*	Current MPH
9	*Non blast lbs*	Total non blast lbs since reset
10	*blast feet*	Total blast feet since reset
11	*blast lbs*	Total blast lbs since reset
12	*liquid feet*	Total liquid feet since reset
13	*liquid gals x 10*	Total liquid gals x 10 since reset
14	*miles x 20*	Total miles x 20 since reset

15	*road temp*	Road Temperature
16	*air temp*	Air Temperature
17	*product #*	Product No.: 1=Sand, 2=Salt, 3=Alt 1, 4=Alt 2, 5=Alt 3 & 6=Anti Ice
18	*hh*	Hour (2 digits)
19	*mm*	Minute (2 digits)
20	*ss*	Second (2 digits)
21	*Day of week*	day of week (Sunday as 1)
22	*month*	Month (2 digits)
23	*Day*	Day (2 digits)
24	*Year*	Year (4 digits)
25	*VID*	Vehicle ID (6 digits)
26	*Digital Ins*	Check Sum number
27	*Boom In*	8 bit analog value
28	*Plow Position*	Plow Position (0=up, 1=down)
29	*Road Condition*	Road Condition
30	*Weather Condition*	Weather Condition
31	*Chemical Spread*	Amount of Chemical Spread in lbs/mile
32	*Exception*	Exception file indicator: P=Plow, N=Not exception (Chemical Spread), E=Road Problem, S=Spot Mode

Table 6 - Data File Structure

GPS data (Fields 1-6)

The longitude and latitude are transformed into UTM coordinates using the WGS84 Geodetic system. Time is converted from GMT time to Eastern Standard Time. Speed is converted from knots to mile per hour. Distance is calculated in meters.

Muncie data (Fields 7-28)

Plow position (Field 28) is determined based on the check sum number (Field 26). Chemical spread (Field 31) is calculated using the amount of chemical (blast and non-blast, Fields 9 and 11), in pounds, and miles traveled (Field 14) over the 3-minute time interval. Plow position is determined by placing a sensor in the hydraulic line to detect hydraulic fluid back pressure.

Data from GPS and Muncie Controller are merged with the user input data. In the case of “Report Road Problem” and “Report Spot Mode Location”, only the location data will be sent to the server.

Driver Input (Fields 29 and 30)

The driver selects a value for each field.

Chemical Spread (Field 31)

This value is calculated from Muncie fields 9, 11 and 14.

Exception (Field 32)

This field contains the exception code.

File Management

This data file is sent every three minutes over the SAFE-T network to the AVL server in Indianapolis (see Figure 2). File management software was developed to combine the truck data into a master merged text file. This merged data file is then saved to the Oracle server at a three minute interval. The map reports use the GISMAP server and ARCIMS software, developed by the INDOT GIS section, to retrieve data from Oracle and display it on state GIS maps.

Map Based Reports

The map reports display truck data in real time (3 minute delay). Also archived data can be displayed. The map application displays in layers truck speed, application time, application rate, chemical type, road condition, weather condition, and road temperature. As an example figure 6 shows the truck speed. The upper right portion of the screen is the legend that describes the symbol values used on the map.

Figure 7 shows additional truck data and how layers can be turned on and off.

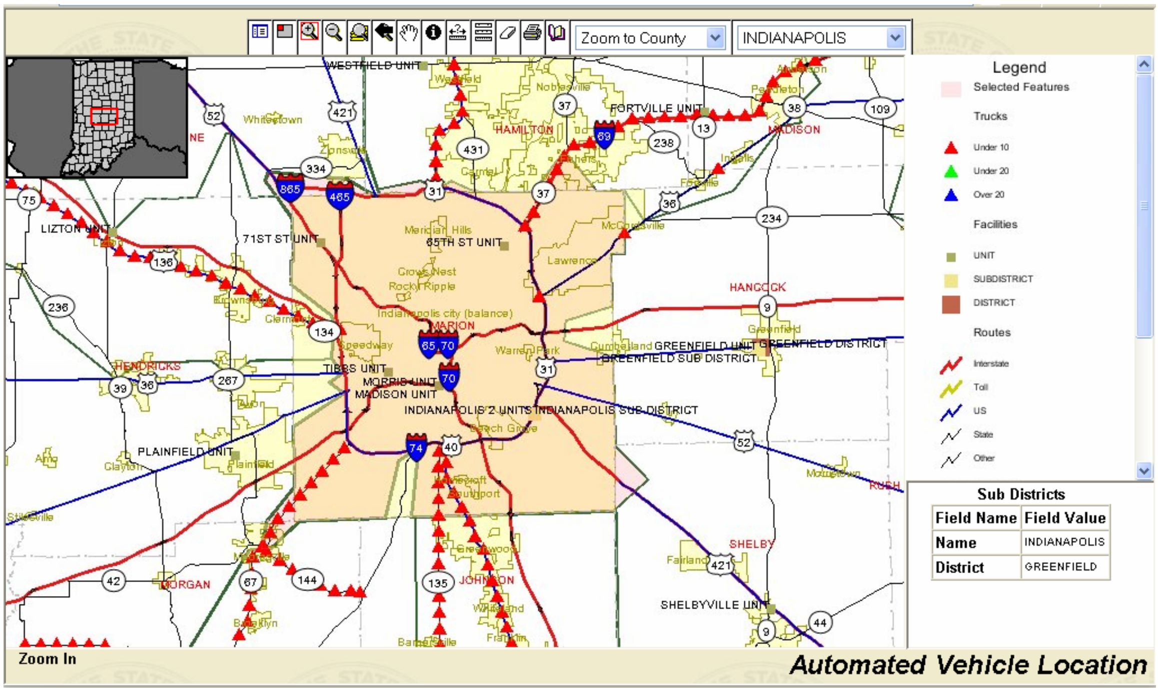


Figure 6 –GIS Speed map

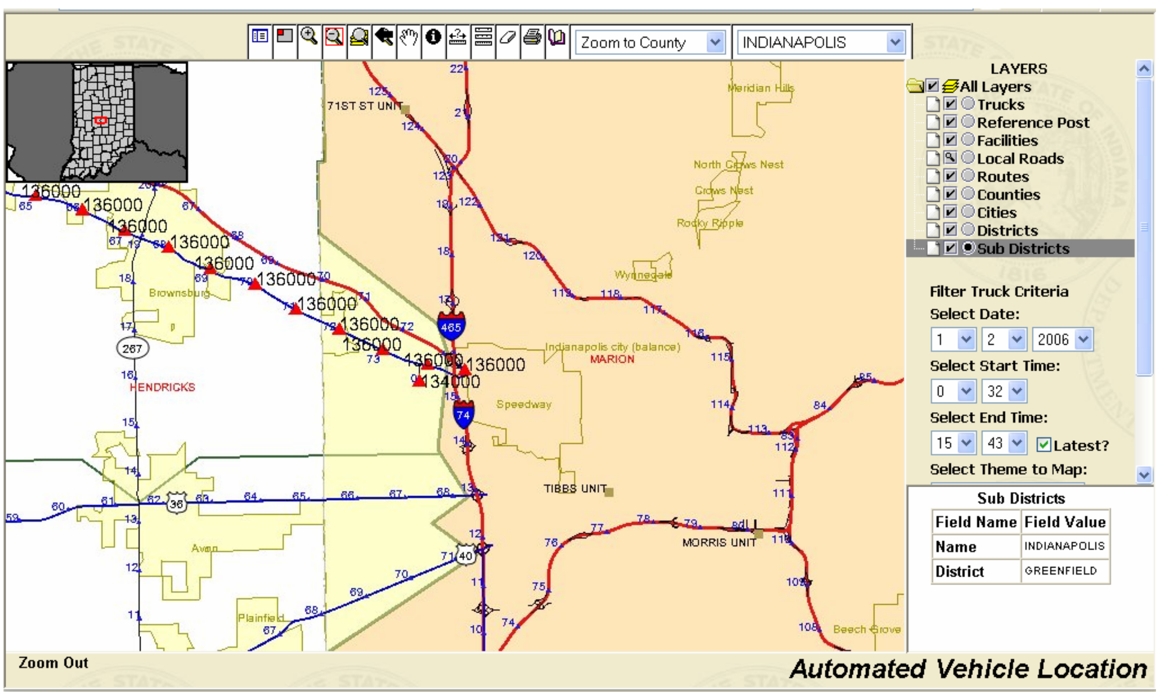


Figure 7 –GIS MAP

Developing MDSS Interface

One project activity was to develop an interface into the Maintenance Decision Support System (MDSS). This is an application developed and operated by Meridian Environmental Technology and INDOT is participating in. The objective is to develop a transfer mechanism for the truck data to feed into MDSS.

Data Format

Based on input from Meridian (Steve Gaddy), MDSS needs the following data:

- Date/Time (any common format will do)
- Vehicle ID
- Latitude (degrees N)
- Longitude (degrees W)
- Road Temp (degrees F)
- Air Temp (degrees F)
- Plow Position
- Road Condition
- Weather Condition

For chemical data, MDSS needs:

- Applied product (product field)
- Amount of product per lane mile such as liquid/solid rate corresponding to the product type

Since both INDOT and MDSS data files are in comma separated value (CSV) format, creating the data file is fairly simple. To successfully accomplish this, the header of the two data tables should correspond so that MDSS can read INDOT data files. Three possible chemical types are salt, sand, and liquids and their application amounts can be calculated from INDOT data and used in MDSS.

Location Data

GPS raw data gives the longitude and latitude in degree. To display it on the INDOT AVL maps, the units are converted from degree to X and Y in the UTM coordinates (Assumption: WGS84 Geodetic Coordinates in the input). MDSS needs latitude and longitude in degrees with 5 to 6 decimals, and this is provided in the INDOT data file.

Options to transfer data files

MDSS collects data from a source at defined time intervals, typically every 5 minutes, but since the INDOT system does it every three minutes Meridian uses that time interval. Meridian worked with the INDOT GIS section to develop a connection to a secure FTP service. The master merged data is placed there every three minutes and Meridian fetches it into MDSS.

Meridian made several tests at establishing this connection. One recommendation from Meridian is to match the headers with the data. Currently some of the headers are misaligned. Otherwise a connection was established at the end of the 06-07 winter season.

Wireless Data Transfer System Using Hotspot and VPN

Another project objective was to test the option for transferring data in batch upload through a hotspot connection.   Using this method, data is collected in the truck and when the truck comes within range of a wireless hotspot a connection is made and data transferred. A hotspot could exist at the unit so when the truck returns the data transfer occurs. In this case the data is not real time but delayed in reporting, which is a negative with this approach. The positive is a modem or cellular device is not required in the truck for data transfer. The below figure illustrates this concept.

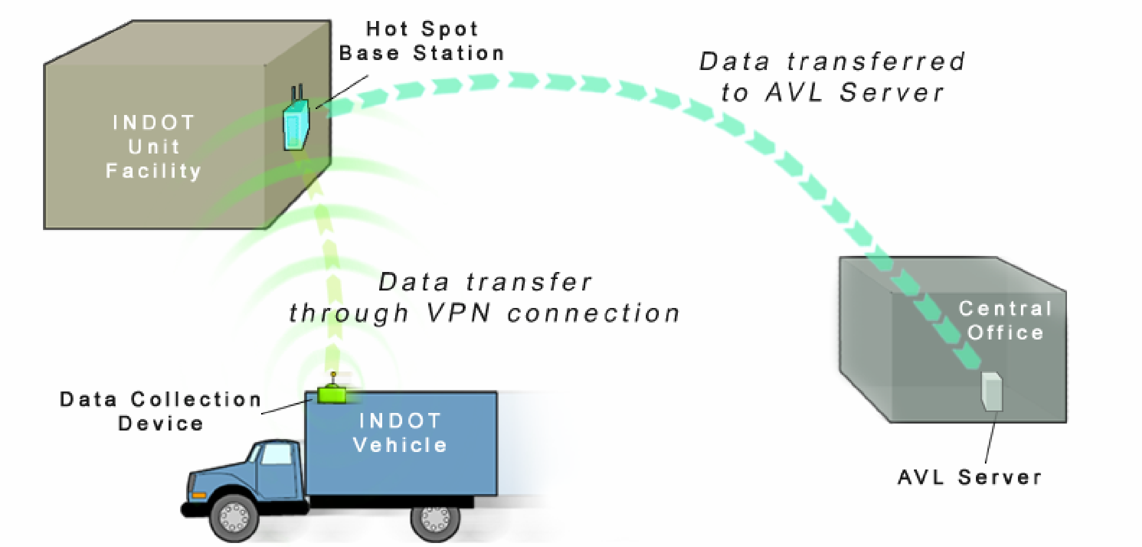


Figure 8 - Hotspot Option

Some particulars about this system and tests are provided next.

<u>Enhanced Security with Encrypted Wireless Network and VPN Connection</u>

The drivers are required to input ID's and passwords to access encrypted wireless network system and the Virtual Private Network (VPN) server, which provide enhanced security for data transmission from clients (vehicles) to the server (base station).

Typically, a user (driver) is prompted to input ID and password for wireless network access. This is required for the users (truck drivers) to securely transfer their data to the base station when they enter a hotspot zone.

<u>WiFi-enabled Hotspot Using 802.11n technology</u>

This setup requires the following equipment:

1. Base computer
2. Wireless-N (802.11n) router
3. Laptop (Client) with wireless-N (802.11n) adapter

B. Hardware Cost

1. Linksys Wireless-N Broadband Router (WRT300N): $149.99
2. Linksys Wireless-N Notebook Adapter (WPC300N): $119.99

C. Test Results

Based on the test results, 802.11g can be used up to 35 yards and 802.11n over 90 yards for file transmission.

1. Hotspot Reception Test (Open Area)

Distance (yd)*		**Signal Strength**		**Speed (Mbps)**		**Internet Access****	
802.11g	802.11n	802.11g	802.11n	802.11g	802.11n	802.11g	802.11n
5 - 9	less than 5	5	5	2 - 50	81 - 270	Excellent	Excellent
8 - 20	5 - 25	4	4	2 - 18	54 - 108	Good	Excellent
21 - 24	20 - 30	3	3	1 - 2	81	Fair	Excellent
36 - 47	30 - 90	2	2	1	11 - 39	Poor	Good
over 50	90 - 140	no signal	1	no signal	5 - 26	no signal	Good
-	140 - 150	-	1	-	up to 11	-	Fair
-	over 150	-	no signal	-	no signal	-	no signal

Table 7 – 802.11 Comparison

* Distance (yd): Approximate yardage
802.11g can be used up to 47 yards at maximum and 802.11n up to 150 yards at maximum from a wireless router. (802.11n about three times farther than 802.11g)

** Internet Access
Excellent: No complaints in using the Internet at all
Good: Intermittent delay in navigating a webpage to another, no problems with playing streamed videos
Fair: Some stoppage in playing streamed videos, but overall okay to use the Internet
Poor: Hard to watch streamed videos and long delay to open a website

2. File Transmission Test (Open Area)

Distance (yd)	Signal Strength		Speed (Mbps)		duration (second)*		file size (mb)	
	802.11g	802.11n	802.11g	802.11n	802.11g	802.11n	802.11g	802.11n
At base station	5	5	48	270	42	42	2	2
At base station	5	5	48	270	43	41	2	2
up to 5	5	5	24	270	43	40	2	2
up to 5	5	5	48	270	23	26	1	1
up to 5	5	5	48	270	21	26	1	1
up to 5	5	5	48	243	10	8	0.5	0.5
up to 5	5	5	48	270	10	6	0.5	0.5
5	4	4	24	243	43	43	2	2
10	4	4	2	270	42	42	2	2
15	4	4	11	243	43	41	2	2
20	4	4	1	216	90	43	2	2
25	3	3	1	162	45	43	2	2
30	3	3	11	135	43	43	2	2
30	3	3	11	135	45	41	2	2
35	2	2	1	81	47	43	2	2
40	2	2	1	54	55	42	2	2
50	2	2	1	39	fail	42	2	2
70	2	2	1	39	fail	42	2	2
90	2	2	1	39	fail	43	2	2

Table 8 – File Transmission Test

* Duration (second)
File transmission speed was almost the same for both 802.11g and 802.11n.

Secured Data Transfer Method through VPN Connection

A. VPN (Virtual Private Network)

Virtual Private Network (VPN) is a secure, private communication system. Most VPN implementations use a public network like the Internet as Purdue VPN does. As a point-to-point connection, VPN clients authenticate users, encrypt data, and otherwise manage sessions with VPN servers utilizing a technique called tunneling. Just like Intranet users, only authorized users can access the VPN server using ID's and passwords.

B. Configuring VPN Service in Windows Server 2003

The AVL server would have to be configured as a VPN server.

C. File Transfer test result

A file transfer testing was done by transferring files from a local computer(client machine) on the Purdue network to a secured folder on a Purdue server that is running

Windows Server 2003. With the testing, it was confirmed that the files can be transferred to the server through a secured VPN path by mapping a secured folder in the server. The users are required to input their ID's and passwords at least twice when they connect the VPN server and map the secured folder in the server. All procedures, however, can be set up automatically as long as the logins and passwords match to the VPN and the server.

<u>Summary</u>

The use of hotspot and VPN connection provides network users with secured access to a server. Based on the tests, it was confirmed that this system provides enhanced security for data transmission from clients to the server because it requires multiple security checks to transfer files to the server. All can be set up automatically. Besides, the hotspot test results showed it is possible that the users can securely transfer their data to the base station as soon as they get into a WiFi-enabled Hotspot, over 90 yards with upcoming new wireless standard (802.11n), without having to save the data to another media and manually copying it to the base station. Therefore, this system enhances the performance of secured wireless data transmission.

Using Pocket PC/Smart Phone Devices to Transfer Data

Due to data transmission difficulties experienced with the Motorola modems, another option was explored that utilized a smart phone to transfer data. Smart phone is a mobile phone that was originally designed to have email and basic personal organizer functionalities while a pocket PC is a personal computer like handheld device with condensed functionality.

<u>Operating Systems</u>

Both smart phone and pocket PC devices have different platforms, but similar functionalities. The different operating systems are Symbian, Linux, Windows Mobile, RIM and Palm OS.

The newest Windows operating system for such device is Windows Mobile 6.0 that was released in February 2007 with separate versions for each device. The smart phone version does not have touchscreen capability, the pocket PC phone version is the PDAs version with phone functionality, and the PDA version is the plain PDAs without cellular radios. Photon is the operating system that combines the pocket PC phone and the smart phone version of Windows Mobile 6. This operating system will be launched in 2008.

<u>Serial Communications</u>

With a serial RS232 interface in these mobile devices, data transfer can be established through serial communication. This data transfer application can be developed using visual basic.net.

Wireless Data Transfer to Server

Data can be transferred from a pocket PC/ smart phone to another computer through GPRS (General Packet Radio Service). For corporate networks, a VPN (Virtual Private Network) connection is necessary. The below figure describes this method of transferring data.

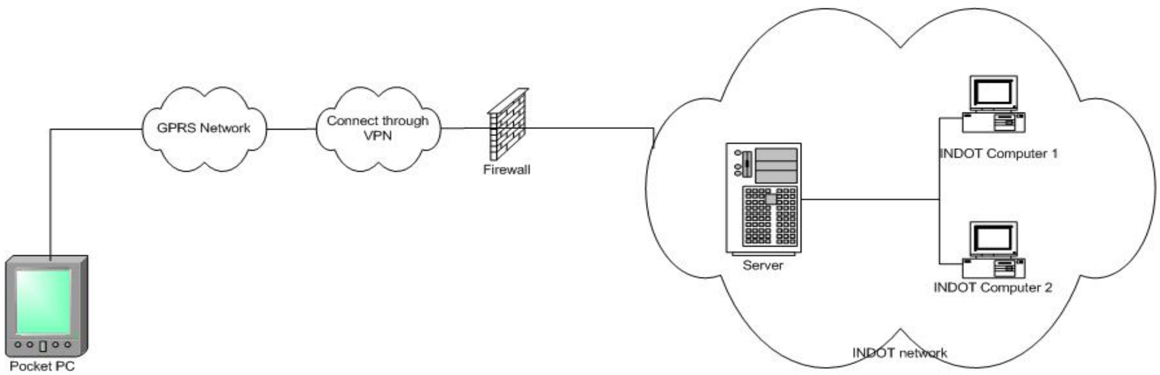


Figure 9 - Data transfer with Mobile Device

System requirements for Pocket PC/ Smart Phone

Operating System: Windows Mobile 5.0 or higher
Interface: Serial RS-232 for serial communication, Bluetooth
Data plan: GPRS data plan with capability for VPN connections
Device cost: Pocket PC phone cost is usually under $500. This varies with service provider, the cost may be lower with service contract.

Data Plan cost

Some data plans use a public access point that does not allow VPN connections. The data plan should include a private access point that allows VPN connections to the server. The below table contains the current data plans for Cingular, Verizon and Nextel.

Provider	Plan Name	Monthly Cost
Cingular	Enterprise Data Connect Plan	$84.98 ($44.99 plus the regular cellular plan cost $39.99)
Verizon	Core Connect Plan	$79.99 ($49.99 plus the cellular plan cost)
Nextel	Blackberry Unlimited Email and Web	$89.98 ($49.99 plus the cellular plan cost $39.99)

Table 9 – Cellular Service Comparison

Summary

In conclusion, the application can be implemented through a pocket PC phone. By eliminating the computer and the wireless modem, the overall system equipment cost can be reduced dramatically. Since there are fewer hardware components involved, the installation of the equipment will be easier. The below table compares overall costs between this option(Option 1) and the Motorola option(Option 2) in 1000 trucks.

Options	**Hardware**	**Parts**	**Model / Vendor**	**Cost per Part**	Subtotal	**Total Maximum Cost**
Option 1	In-Vehicle Equipment	GPS receiver + Modem + Data Terminal	Multiple Vendors	$500.00 / vehicle	$500,000	$3,500,000.00
	Service Fee		Multiple Vendors	$3000 / 5 years / vehicle ($50 / month / vehicle)	$3,000,000	
Option 2	In-Vehicle Equipment	GPS receiver	GPS 18 / Garmin	$130.00	$3355.00 per vehicle	$3,753,390.00
		Radio Modem + Antenna	VRM 850 / Motorola	$1,900.00		
		Rugged Laptop	ML 850 / Motorola	$1,200.00		
		IP Setting Software	MWCS2 / Motorola	$125.00		
	Base Station		AVL server	$ 5,000	$398,390.00	
	Map-Based Control Software		PU/INDOT	$ 0		
	File Transfer Module		PMDC Application Software / Motorola	$393,390.00		

Table 10 - Cost Comparison for 1000 trucks over a 5 Year Period

Conclusions

This project's main objective was to develop and test a Winter Operations System that utilized the statewide wireless network called SAFE-T. The system was tested over a two year winter period. The other objectives of developing an MDSS interface and hotspot batch data transfer were completed as well. What transpired in this project is described in this report. The conclusions are described in this section.

The first winter season, 05-06, four trucks at two locations, 2 in Monticello and 2 in Columbus, were equipped and tested. This winter had very few winter weather events to test the system by. Also, when the system was tested several bugs and software issues were discovered. The drivers had problems logging in and determining if the truck was communicating over the wireless network. Also, they suggested modifications to the software and input screens. As a result of this testing period, changes were made to the software during the summer of 2006.. These changes were:

- Revised screen look
- Added plow position – up or down
- Added road temperature
- Added spot application and trouble spot recording
- Removed login
- Eliminated Vehicle ID input

Before the winter of 06-07, the application was expanded to three locations and 10 trucks. Also in this expansion three different hardware data collection devices(computers) were to be tested. The testing program looked like this:

LaPorte	- 1 Mini PC, 1 touchscreen laptop, 2 ultra mobile tablets
Monticello	- 1 Mini PC, 1 touchscreen laptop, 1 ultra mobile tablet
Columbus	- 1 Mini PC, 1 touchscreen laptop, 1 ultra mobile tablet

These systems were used for the whole winter season. Screen resolution, icon size and fonts were adjusted to the optimum to improve the usability of the program in the vehicle.

Winter activities in 06-07 were again below normal and most did not occur until February 2007. During this limited time field testing occurred with the following results.

1. Several problems occurred with showing data on the GIS maps. These were resolved and fixed by placing an executable program on the GIS server that archives data to Oracle and places the data on the maps.
2. Drivers experienced fewer problems with the software because it was easier to understand and operate.
3. The modems experienced numerous problems at Monticello and Columbus due to frequency shifts which caused loss of data transfer.
4. It is difficult for drivers to monitor connection status while driving.

5. Drivers preferred laptops.
6. Data transferred successfully into MDSS.
7. The power source of the system was connected to the cigarette lighter of the vehicle for easier disassembly. Based on the evaluation, it is recommended to connect the power cables directly to the vehicle battery because of the adverse road conditions.
8. Change the GIS maps to indicate the latest position of the trucks and revise some of the legend symbols and colors.
9. Features that managers liked:
    - Ability to track trucks and retrieve this information at a later date.
    - Know how much chemical was placed and at what time.
    - Combining the AVL info with MDSS provides better information to base decisions.
    - Helps in updating the weather info.
    - Provides a way that law enforcement & private citizen could see that trucks were out on routes.
    - It could be a tool to show how much time is spent on keeping roadway safe for motoring public.
    - Help save on material use by having current weather info.
    - Tracking employees and trucks to be able to answer calls when a truck or where a truck is on a route and better customer service.

Driver evaluations were distributed to collect their input on the system. Only one was returned with average values on the question. A sample evaluation form is included in the Appendix.

Recommendations

In the end the project developed many solutions; AVL system, MDSS interface, Map based reports, Hotspot data transfer. But it also created many questions. The Study Advisory Committee for the INDOT project decided to seek an extension to the project to seek solutions to some of these questions. The scope of the extension would include the following:

- Investigate the alternative of collecting and transferring data through a PC/Smart Phone device.
- Determine if any other options exist for data transfer within the state.
- Investigate using the system for summer activities.
- MDSS and INDOT AVL both have a map. Which map best fits INDOT needs, or are both needed, and which one is the most economical option?
- Can other programs (WMS, 511) also use the equipment in the trucks?
- Develop data interface into CARS system that is to be implemented by INDOT in 2007.
- Consider potential hidden costs from IOT.

- What are the effects on operations?
- Is it cost beneficial?
- What would be the cost of implementation?
- What would be needed to implement and over what time period?

These are some of the issues to describe the scope with. Once a scope has been defined then cost and time requirements will be calculated and submitted to INDOT Research for approval considerations.

Appendix

Mini PC Configuration

700 TS - 7" USB Touch Screen LCD Monitor with VGA input
MP-SC3 Mini P4-Class Aluminum Mini PC
Processor: Intel Celeron 2.0 GHz
Memory: 512 MB PC 3200 DDR (256MBX2)
Hard Drive: 20 GB 4200 RPM HDD
24x CD-ROM Tray
Microsoft Windows XP Pro
Mounting Bracket

Laptop Configuration

Fujisu LifeBook B6210 Core Solo U1400 ULV
Memory: 2MB Cache, 512MB RAM DDR2 SDRAM
Modem: V.9, 56 Kbps, Fax analog
Networking: Gigabit Ethernet IEEE 802.11 a+b+g
Operating System: Win XP Pro
Processor: Mobile Intel 945GM Express, Data bus speed: 533 MHz, Processor Speed: 1.2 GHz, Intel Core Solo U1400
Storage: ATA-100, Hard Drive Capacity: 40GB
Video: 12.1 in LCD 1600x1200(ext), 1024x768(int), Intel Graphics Media Accelerator 950

Tablet Configuration

Samsung Q1 Ultra Mobile Tablet PC, Intel Celeron M, 900 MHz, ULV
Memory: 512KB L2 Cache, 512MB, 400 MHzDDR2 SDRAM
Networking: Bluetooth 2.0, Bluetooth2.0 EDR, IEEE 802.11b,g, Ethernet, Fast Ethernet, Network adapter
Operating System: Win XP Tablet PC Edition 2005
Processor: Intel Celeron M ULV, Clock Speed: 900MHz
Storage: Mobile Intel 915GMS Express, Data Bus Speed: 400 MHz, Hard Drive Capacity: 40GB, 4200 rpm, Portable
Video: 7 in, WVGA, 800x480, Intel GMA 900

Driver Evaluation

Automatic Vehicle Location Evaluations   Name: ____________________

Please circle your response.

Location:	LaPorte	Monticello	Columbus
Usage Frequency:	Low (during snow only)	Medium (during snow and occasionally during normal operation)	High (during snow as well as normal operation)
Computer Interface:	Mini PC	Laptop	Tablet

Rating scale: 5 being the best

Hardware

Questions	Ratings	Comments
Please indicate your satisfaction with the hardware.	5 4 3 2 1	

Computer Interface

Items	Ratings	Comments
Screen viewable size	5 4 3 2 1	
Screen resolution, size of icons and font size	5 4 3 2 1	
Brightness	5 4 3 2 1	

Software

Questions	Ratings	Comments
Please indicate your overall satisfaction with the software.	5 4 3 2 1	
User friendliness	5 4 3 2 1	
Do you have any additional comments? Please explain.		