Utilizing Wireless Data Network for AVL and Mobile RWIS

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ABSTRACT

Indiana has a statewide wireless network (SAFE-T) that has been primarily used by the state police. It has enough capacity to accommodate other users. The Indiana Department of Transportation (INDOT) has developed a winter operations tool that utilizes GPS, sensors to produce real-time information on chemical distribution, road temperature and plow position, and road and weather conditions.

The data collected at the maintenance vehicle (snow plow) produces maps of time of chemicals placed, type of chemical, application rate, vehicle speed, road temperature, and plow position. Also, road and weather conditions can be displayed. Another feature of the system is transferring the appropriate data into a maintenance decision support system (MDSS).

In the 2006–2007 winter, ten snow plow vehicles were equipped with the equipment described above. The equipment was placed in vehicles at three locations: Laporte, Monticello, and Columbus. This paper describes the results of system tests for the last two winters. Also, a summer application, paint stripping, will be described.

Keywords: AVL—RWIS—winter operations—wireless
INTRODUCTION

Indiana Department of Transportation (INDOT) has developed and tested two automated vehicle location (AVL) systems. One is a winter operation application that tracks and manages snow and ice removal activities. The other application is a summer activity that tracks and records roadway painting operation. Both applications will be described.

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 research project at INDOT has utilized the statewide wireless data network, SAFE-T, for data transfer. Other appropriate data transfer options that are being investigated and tested are a wireless hotspot and using a cellular data network.

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 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.

AVL OPTIONS

Two AVL options were initially 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. A summary of the cost comparison is in Table 1. 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. INDOT has approximately 1,100 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.

Option 2 is considerably less expensive due to the monthly service charge required in Option 1.
Table 1. Cost comparison after year 5 between Option 1 and Option 2

<table>
<thead>
<tr>
<th>Year</th>
<th>Option 1 Additional Cost</th>
<th>Option 2 Additional Cost</th>
<th>Total</th>
<th>Option 1 Total</th>
<th>Option 2 Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 5</td>
<td>$4,500,000.00</td>
<td></td>
<td></td>
<td>$3,753,390.00</td>
<td></td>
</tr>
<tr>
<td>Year 6</td>
<td>+ $720,000¹</td>
<td>+ $32,304.00²</td>
<td>$5,220,000.00</td>
<td>$3,785,694.00</td>
<td></td>
</tr>
<tr>
<td>Year 7</td>
<td>+ $720,000</td>
<td>+ $33,596.00</td>
<td>$5,940,000.00</td>
<td>$3,819,290.00</td>
<td></td>
</tr>
</tbody>
</table>

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
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 was Laporte, and the truck distribution is as follows:

- Laporte: 4
- Monticello: 3
- Columbus: 3

![Conceptual diagram of INDOT AVL network using SAFE-T radio network](image)

*Figure 2. Conceptual diagram of INDOT AVL network using SAFE-T radio network*

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.

![Vehicle hardware diagram](image)

**Figure 3. Vehicle hardware diagram**

*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.

*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.

*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 (Figure 4).
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 startup. 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.
File Management

This data file is sent every three minutes over the SAFE-T network to the AVL server in Indianapolis. 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 ARClMS 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 (three-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 5 shows additional truck data and how layers can be turned on and off.

OTHER WIRELESS DATA TRANSFER OPTIONS

Due to difficulties experienced with the Motorola modems, other data transfer options were investigated. This next section describes two: hotspot and cellular data networks.

Hotspot and VPN

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. Figure 6 illustrates this concept. In the figure, a virtual private network (VPN) is a secured network that requires login and password.
In this case the data is not real-time but delayed in reporting, which is a negative with this approach for winter operations. The positive is a modem or cellular device is not required in the truck for data transfer. This option will work for summer operations where real-time data is not required.

![Diagram](image)

**Figure 6. Hotspot option**

**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.

*Operating Systems*

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 touch screen capability; the pocket PC phone version is the PDA’s version with phone functionality, and the PDA version is the plain PDA 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.

*Serial Communications*

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 General Packet Radio Service (GPRS). For corporate networks, a VPN connection is necessary. Figure 7 describes this method of transferring data.

![Data transfer with mobile device](image)

**Figure 7. 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.

**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. Table 7 compares overall costs between this option (Option 1) and the Motorola option (Option 2) in 1,000 trucks.
Table 7. Cost comparison for 1,000 trucks over a five-year period

<table>
<thead>
<tr>
<th>Options Hardware</th>
<th>Parts</th>
<th>Model / vendor</th>
<th>Cost per part</th>
<th>Subtotal</th>
<th>Total max. cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Option 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-vehicle</td>
<td>GPS receiver, modem, data terminal</td>
<td>Multiple vendors</td>
<td>$500.00 / vehicle</td>
<td>$500,000</td>
<td>$3,500,000.00</td>
</tr>
<tr>
<td>Service fee</td>
<td>N/A</td>
<td>Multiple vendors</td>
<td>$3,000/ 5 years/ vehicle ($50 / month / vehicle)</td>
<td>$3,000,000</td>
<td></td>
</tr>
<tr>
<td><strong>Option 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-vehicle</td>
<td>GPS receiver</td>
<td>GPS 18 / Garmin</td>
<td>$130.00</td>
<td>$3,355.00 per vehicle</td>
<td>$3,753,390.00</td>
</tr>
<tr>
<td>Radio modem, antenna</td>
<td>VRM 850 / Motorola</td>
<td>$1,900.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rugged laptop</td>
<td>ML 850 / Motorola</td>
<td>$1,200.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IP setting software</td>
<td>MWCS2 / Motorola</td>
<td>$125.00</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Base station</td>
<td>N/A</td>
<td>AVL server</td>
<td>$ 5,000</td>
<td></td>
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<tr>
<td>Map-based control software</td>
<td>N/A</td>
<td>PU/INDOT</td>
<td>$0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>File transfer module</td>
<td>N/A</td>
<td>PMDC application software / Motorola</td>
<td>$393,390.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**SUMMER AVL APPLICATION**

The summer of 2007, a paint stripping application was developed and is being tested in the Laporte District. The hardware consists of a laptop and a GPS receiver in the trailing escort vehicle. The laptop has software that collects painting information. The software requires manually selecting the stripe type. Figure 8 is the input screen.

Painting data is accumulated in a data file. Periodically paint data is transferred to the painting supervisor desktop. This data is viewed in a desktop map-object software program developed in VB.net. Stripping info can be viewed by date or date range on the map with corresponding quantities. Figures 9 and 10 are views of the report information.
Figure 8. Paint software

Figure 9. Map-based report
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. Other objectives were to develop a maintenance decision support system (MDSS) interface, a hotspot batch data transfer capability, and, in order to utilize the equipment more, a summer application developed.

The first winter season, 2005–2006, four trucks at two locations: two in Monticello and two 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 2006–2007, the application was expanded to three locations and ten 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 touch screen laptop, 2 ultra mobile tablets
- Monticello: 1 Mini PC, 1 touch screen laptop, 1 ultra mobile tablet
- Columbus: 1 Mini PC, 1 touch screen 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 2006–2007 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:
   a. Ability to track trucks and retrieve this information at a later date.
   b. Know how much chemical was placed and at what time.
   c. Combining the AVL info with MDSS provides better information to base decisions.
   d. Helps in updating the weather info.
   e. Provides a way that law enforcement & private citizen could see that trucks were out on routes.
   f. It could be a tool to show how much time is spent on keeping roadway safe for motoring public.
   g. Help save on material use by having current weather info.
   h. 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.

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 decided to extend the project to seek solutions to some of the following issues:

- Investigate the alternative of collecting and transferring data through a PC/smart phone device.
- 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.
- 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?
ACKNOWLEDGEMENTS

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