McHenry County Implements GIS Technology to Enhance Snow Plow Application

Authors

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Abstract

McHenry County is one of the fastest growing counties in the state of Illinois. During winter months, it is imperative for the McHenry County Division of Transportation to effectively route snow plows to enhance operational efficiency. McHenry County developed a GIS web site to manage the snow plow fleet and to analyze the application of salt along routes in an effort to maximize the use of limited resources. This paper will cover the implementation of Wireless, GPS, laser and other latest technologies for data collection, n-tier distributed system architecture powered by ArcIMS and ArcSDE software, benefits achieved, and lessons learned from our experience.

Background

The McHenry County Division of Transportation (MCDOT) has been proactive by necessity in its winter maintenance operations. Located in Northeastern Illinois along the Wisconsin border, the County gets its share of severe winter weather. MCDOT maintains 230 centerline miles of roadway and approximately 550 lane miles of road. MCDOT cannot support 24 hour coverage with its limited staff; so, running an efficient operation is vital.

The County road system is divided up into 19 snow plow routes averaging 28 miles per truck. MCDOT incorporates additional staff and equipment during large events and at times splits its crew to provide 24 hour coverage but a lower level of service.

MCDOT snow and ice removal systems have evolved in recent years to incorporate the most modern methods and best practices. In 2000, MCDOT added computer controlled dispensing systems. In 2004, MCDOT developed a passive snow plow tracking system. In 2005, MCDOT incorporated the snow plow tracking system into the County-wide GIS. Now, MCDOT can not only track their vehicles and thematically map operational statistics with their offices but also provide data throughout the County and to the public.

Building the Snow Plow Tracking System

Beginning in the year 2000, MCDOT changed its fleet vehicles completely incorporating new upgrades: automatic transmissions, patrol wings, pre-wetting systems, tarps, modern hydraulic systems and computer controlled granular and liquid dispensing systems. In 2004, the decision was made to track operations with passive data; and, a wireless data download was created.

Computer Controlled Dispensing Systems

The computer controlled granular and liquid dispensing systems allowed the operator to dispense materials at precise increments at all speeds. While the units precisely dispense materials, they record operational statistics such as: speed of the vehicle, distance traveled, amount of material dispensed, amount of liquid dispensed, pavement temperature, ambient temperature and several other functions. These early units were not capable of gathering GPS information and MCDOT wanted the ability to track where the plows had been and display the data on a map.

The Tracking System: Live vs. Passive Data

MCDOT's Superintendent of Operations attended many different seminars and gathered information from vendors regarding various GPS tracking systems. Most where active web based systems where the County purchased the hardware, the vendor held the data and the County would be given access. The County had to reassess its position and evaluate why it needed the data live.

It was determined that the data did not need to be live for the following reasons:

- The live systems were cost prohibitive
- Data held be the vendor had a shelf life
- As part of the reassessment, one of the long term goals was to give the public limited information on a web site as to where the plows had been. It was determined that this information should not be live but would need to be updated on a timely manner
- Depending on the system the data may or may not be housed internally

Subsequently, the search for a passive system began. Research showed that most passive systems gathered data and then the organization must physically remove the data from the unit in the truck. This was accomplished using a laptop and a data cable. This was certainly an option but it was time consuming as well.

Going Wireless with the Development of the Drive by Download™ System

MCDOT worked with a vendor to develop a system that would download the data using a wireless connection as the vehicles entered the maintenance shed. The result was the Drive by Download™ system.

The Drive by Download™ system consists of several components that allow the wireless transfer of data from one or many trucks to a central computer. Formatted data can be used to determine how much material (salt, brine, etc) was used in snow removal and ice prevention, what locations the vehicles were at, what time, speed vehicle was traveling, and equipment fault codes, etc. The Drive by Download™ system can be broken down into the following components:

The Drive by Download™ system uses a Garmin® GPS17HVS antenna (**Figure 1**) to receive positional data. A Sprague RoadWatch® sensor is also needed to collect ambient and road surface temperature.

Figure 1. The Garmin® GPS17HVS Sensor

Another component is the spreader control system called the SpreadSmart™ spreader. The SpreadSmart™ spreader controller (**Figure 2**) receives data from sensors, records this information in non-volatile memory, and transmits this data when the vehicle is in range of the base station.

Figure 2. SpreadSmart Rx™

The third component is the wireless ethernet bridge. The system uses standard 802.11 networking technologies to transmit (**Figure 3**) its data to the base station. Using a standard transmission technology ensures availability and compatibility with Windows® compatible computer equipment.

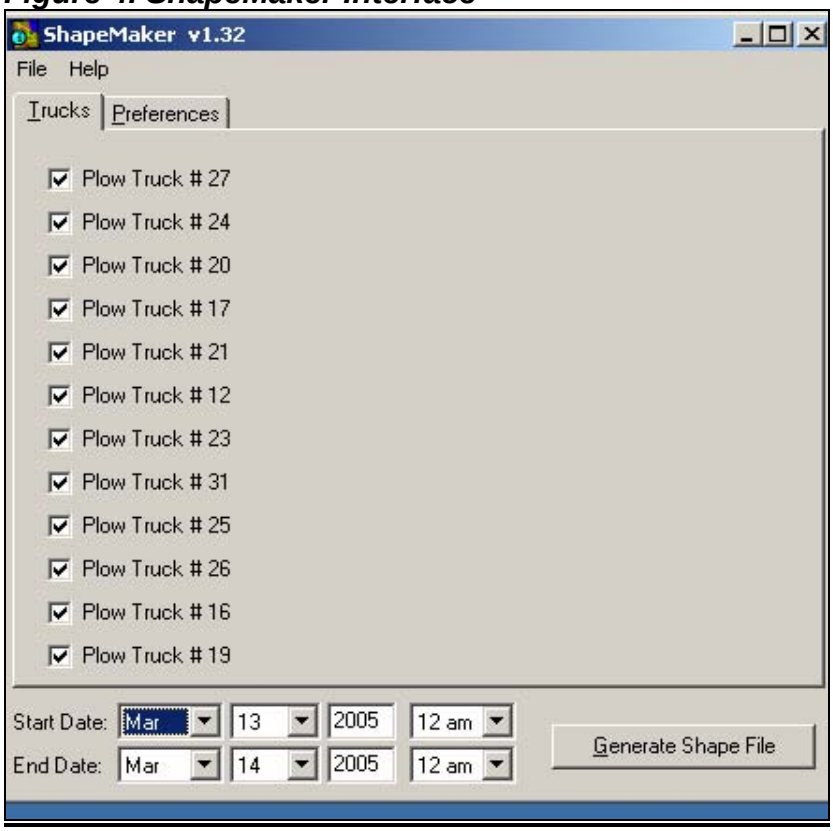
Figure 3. Transmitter

The fourth component that is needed is the wireless access point. The access point is the physical receiver for the data. It is connected to a base station computer which is responsible for managing the wireless connections.

A fifth component is the Drive by Download™ software. This software runs on a standard Windows® platform as a server application. The software checks at a settable interval whether vehicles are in range of the wireless system. If a vehicle is detected, the data transfer process is started, and the data is extracted from the spreader controller. Once finished, the data is stored to the hard drive of the computer (or optionally somewhere on the LAN of the installed site) in an ASCII comma delimited file.

The sixth component of the Drive by Download™ system is the Shapemaker™ software. The Shapemaker™ software (**Figure 4**) is what converts the ASCII comma delimited files into a shapefile. This data can then easily be imported into GIS software such as ArcView, where it can be further manipulated into maps, reports, and other GIS functions.

Figure 4. ShapeMaker Interface



Recognizing the need to refresh skills between winters, a user's guide was created by GIS staff to assist MCDOT staff in viewing shapefiles.

Incorporating Snow Plow Tracking System Into the County-wide Enterprise GIS

Once the data was channeled to a computer in the maintenance section, the data needed to be displayed on a map. MCDOT coordinated with McHenry County's GIS Manager to take the system to the next level. MCDOT wanted a fast and user friendly way of displaying the data was needed on a map without having to have a great deal of knowledge of any GIS software. MCDOT worked with the GIS Manager to create an application that would meet the needs of displaying the data on a map in a user friendly environment.

The GIS Manager worked with a GIS developer (Bruce Harris and Associates), the Superintendent of Operations and the vendor (Cirus Controls) who created the Drive by Download™ system to develop the application as part of the County-wide enterprise GIS and achieve the goals years before expectations.

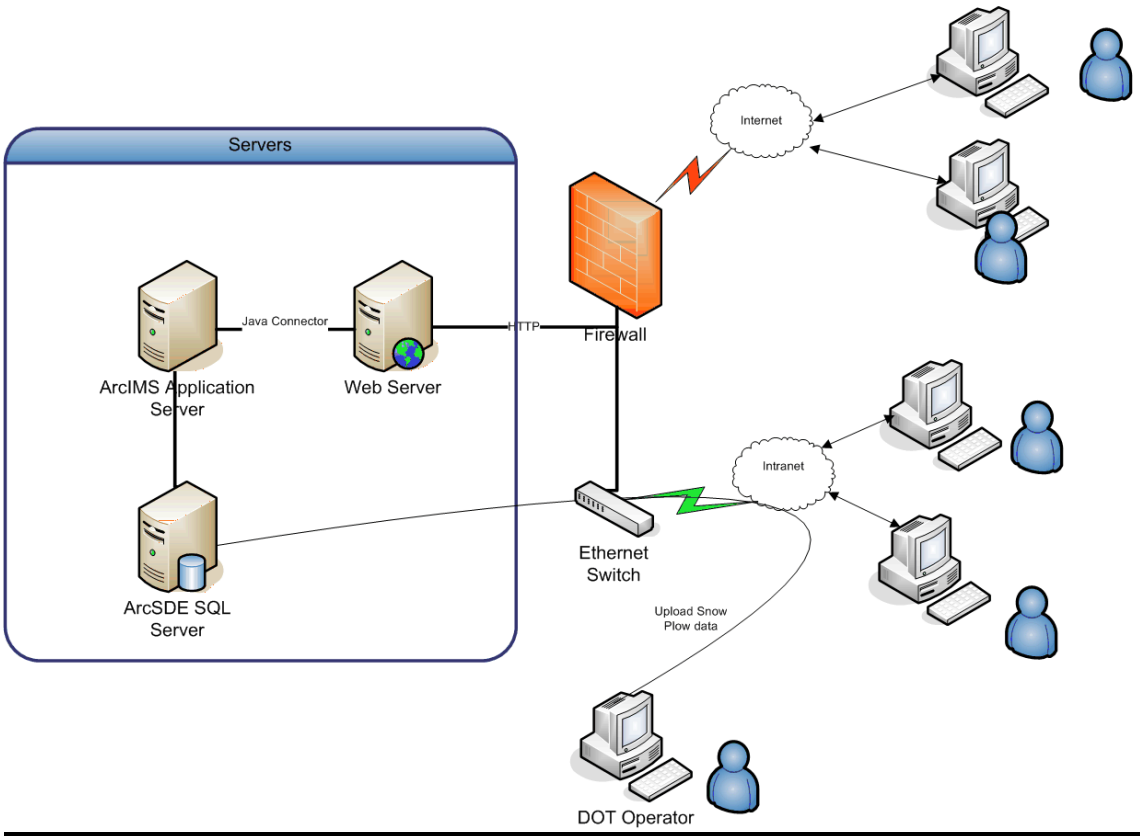
System Architecture

The snow plow tracking system was incorporated into the County-wide enterprise GIS which is powered by ESRI ArcIMS, ArcSDE and ArcEngine Technology. The hardware includes a web server, an ArcIMS application server and ArcSDE Database Server (**Figure 5**).

The snow plow tracking system as part of the County-wide GIS has three components:

1. Snow Plow Uploader
2. Intranet Administration Application
3. Internet Public Viewing System

Figure 5. System Architecture



Component 1. Snow Plow Uploader

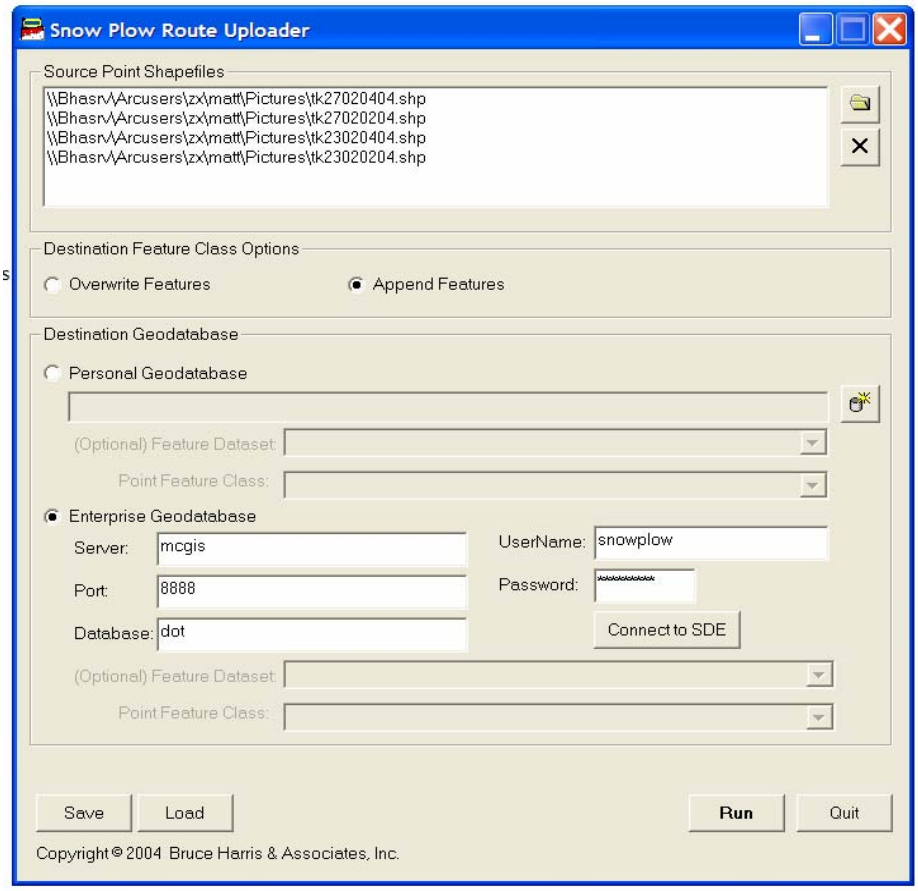
The McHenry County GIS Manager decided that it would be best to have a web based interface that was easy to use and to have the information on the web site update automatically. Using a web-based interface would allow multiple people within MCDOT to view the data without having to have additional GIS software installed on individual computers. The GIS Manager worked with a consultant to develop an interface that would automatically convert the shapefiles to a geodatabase within ArcSDE. This interface is called the Snow Plow Uploader™.

The GIS Manager wanted MCDOT to have the ability to upload the information without having to go into ArcCatalog. This would allow users to upload information without having much knowledge of GIS. The advantages of storing the data within the geodatabase environment are the following:

- The data could be automatically pulled by an ArcIMS application without having to manually update shapefiles.
- Data is stored into three feature classes which enables complex queries of historical data and eases the traditional file management hassle.
- It would also store the data in a centralized environment and access level is defined by user login.
- MCDOT needed to see the information by direction. In order to accomplish displaying the data by a directional basis an offset would be needed to be calculated. A program would be needed to automate this process.
- McHenry GIS Manager can use this Snow Plow Uploader™ to create initial feature class schemas with proper Geodatabase license
- MCDOT Operator can use the program to insert/append new data into the feature classed created with another database login.

The Snow Plow Uploader (**Figure 6**) will upload all the point data into an ArcSDE snowplow_points feature class. After the upload is completed, the points are converted into lines and the snowplow_lines feature class is created, with line angle as an attribute. When converting the points into lines, it allows the viewer to see the data as one continuous flow. At the same time an offset of the snowplow_lines feature class is created and inserted into a feature class called snowplow_offsetlines. The offset is created with an algorithm described in a later section of this paper. Creating an offset of the line feature class allows the viewer to see the direction of the snow plow. This has been developed using ESRI ArcEngine Technology.

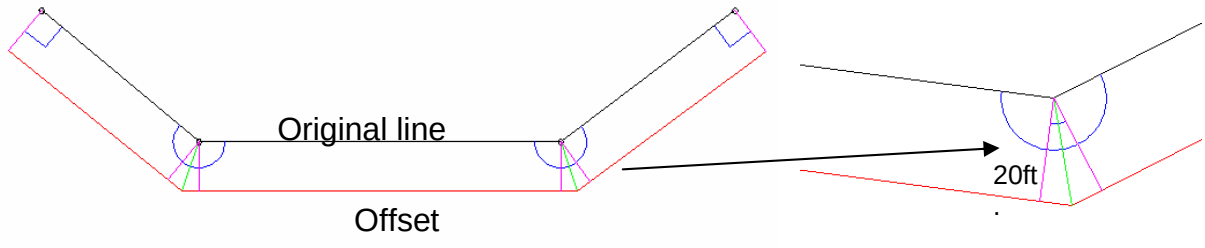
Figure 6. Snow Plow Uploader Interface



Snow Plow Route Uploader Offset Algorithm

The Snow Plow Uploader organizes GPS point data into Route groups based on Truck, Date, and Time. Consecutive points are converted to line segments and appropriate starting and ending attributes are carried to the line feature records. An additional offset polyline feature class is populated to better visually represent trucks traveling on the same road in different directions (**Figure 7**).

Figure 7.

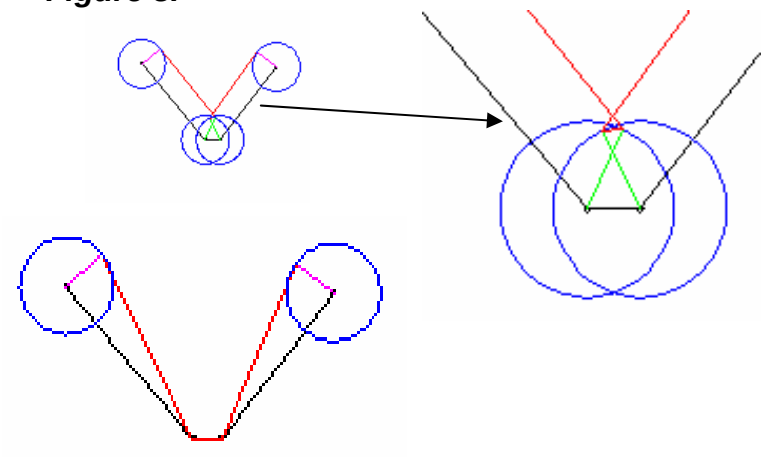


The offset algorithm is an extension of the polyline construction process. It requires existing line features. Every line segment is assumed be between two other segments so a perpendicular mean angle can be established. If the line feature isn't between two other features, i.e. it's the first or last in a route, then the perpendicular angle is used. Since every two sequential line segments have two angles between them (an acute and an obtuse) the angle on the right hand side of the line flow is used. The specified offset distance (20 feet) refers to perpendicular distances, so a hypotenuse distance must be calculated along the perpendicular mean angle to locate a new endpoint for the line segment.

There are two special cases where this logic is not followed:

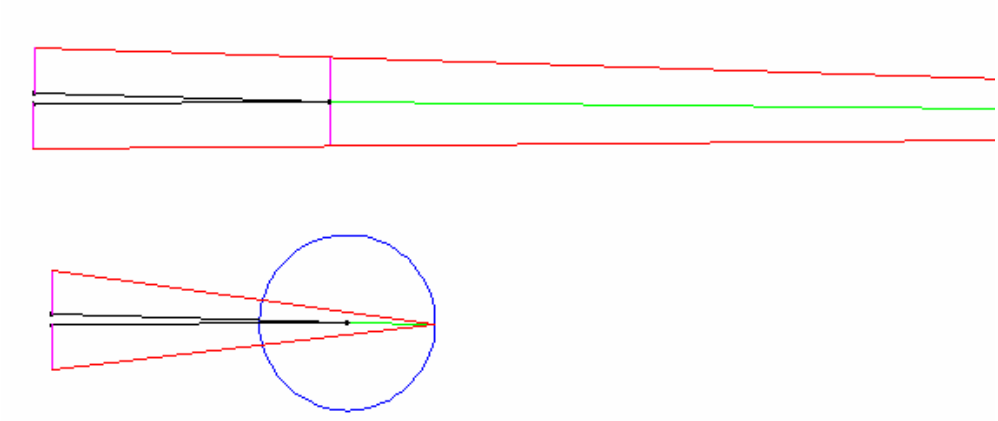
1. If a line segment is less than or equal to twice the offset distance it is possible that an inverse could collapse or inverse the line segment. In these cases the line segment is not offset and any coincident endpoints from other features will remain connected (**Figure 8**).

Figure 8.



2. If two segments change direction so abruptly that the resulting hypotenuse is an unacceptable length then the hypotenuse will be shorted to twice the offset distance (40 feet) (**Figure 9**).

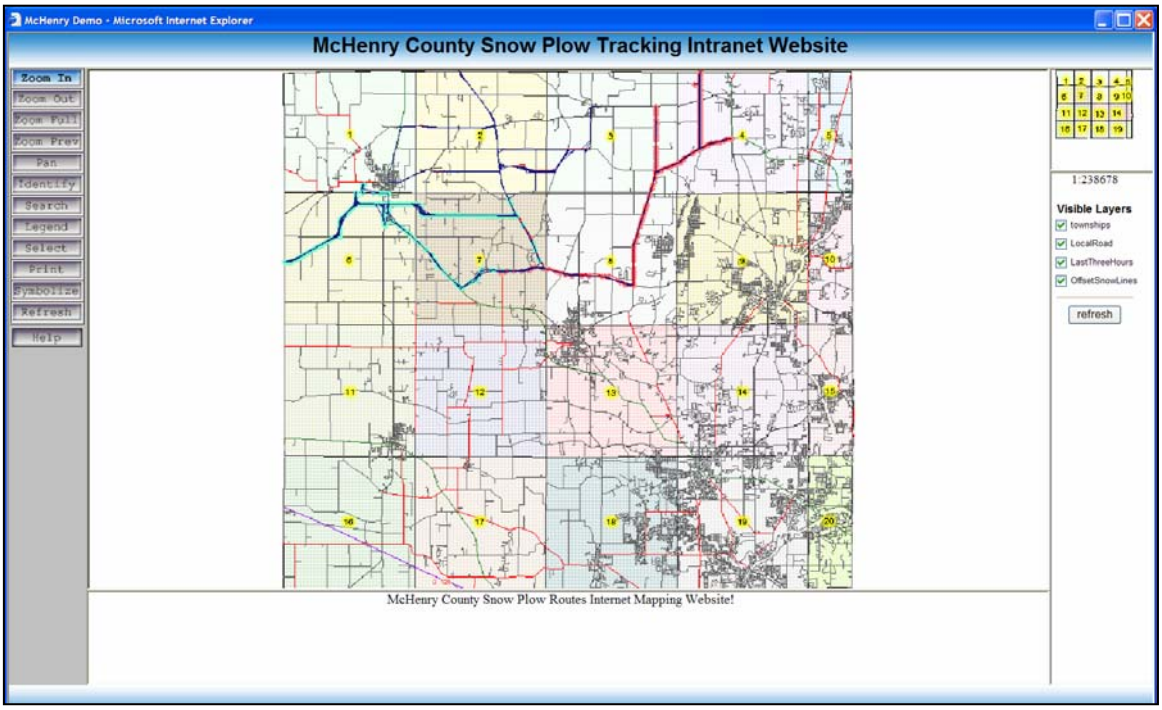
Figure 9.



Component 2.
Developing the Intranet Administrative Application

After the data is uploaded to ArcSDE through the uploader it is automatically pulled by an ArcIMS web site. An intranet application (**Figure 10**) allows the users within the County, with appropriate permissions, to access the snow plow trucks information.

Figure 10. County Intranet Application



By using ESRI ArcIMS technology, this intranet system is built with ArcIMS Java Connector, HTML and JavaScript. Functions of the intranet website include:

1. A map navigation system allows users to zoom in, zoom out, pan and etc.
2. User can use identify tool to get information such as spray mode, pavement temperature, speed, salt applied and etc.
3. User can use legend tool to display current legend, use select tool to select multiple points, and use print tool to print custom map.
4. Show all the snow plow points data collected by snow plow trucks.
5. Show all the original routes
6. For better map display, show the offset routes
7. Display map by driving speed
8. Display map by Truck Number
9. Display map by Route direction
10. Display map by Pavement Temperature
11. Point data is appended to one feature class which allows the ability to query historical snow plow data

Examples of Functions

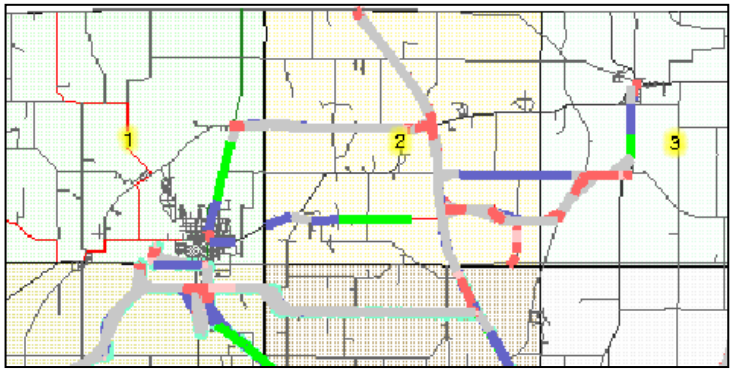


Figure 11. Variations in Speed can be shown thematically for each route.

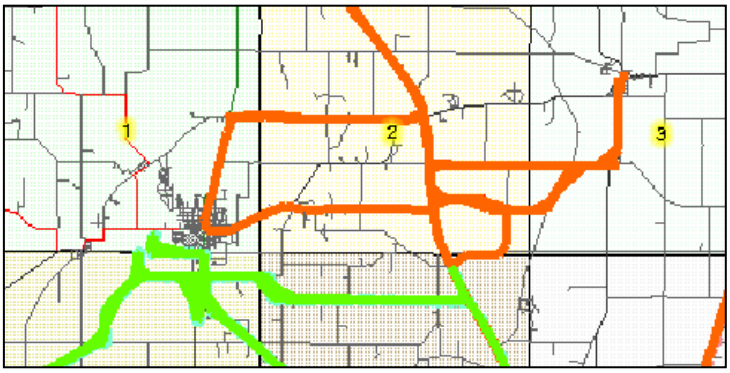
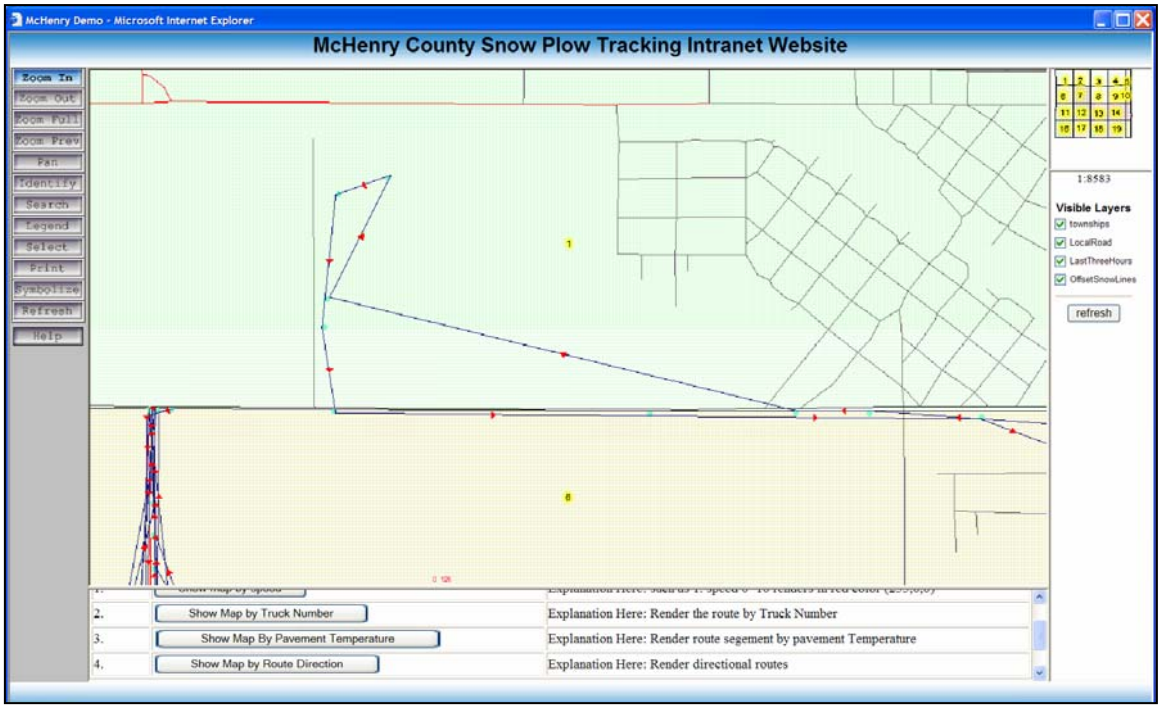


Figure 12. Routes can be viewed by truck number.

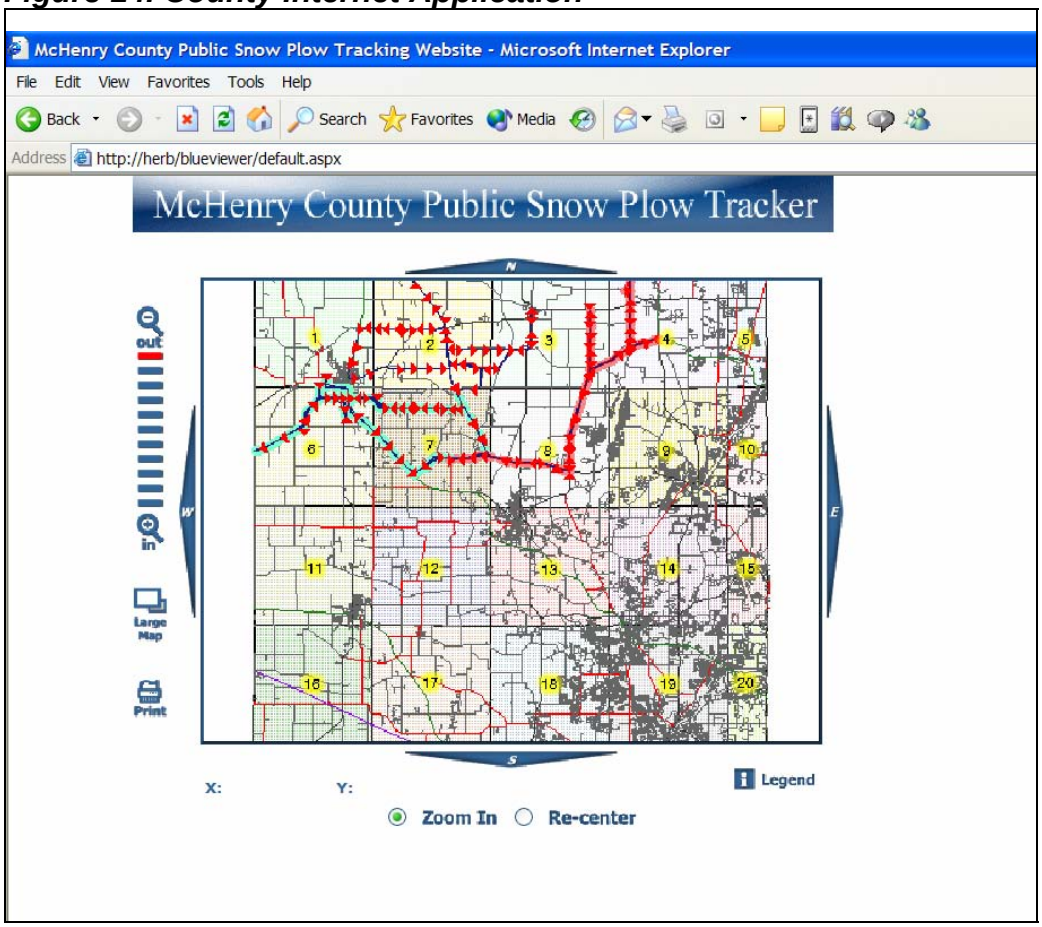
Figure 13. Routes can be viewed by the direction of travel.



Component 3. Internet Application for Public

McHenry County is currently testing a web site that will be deployed on the internet for public use (**Figure 14**). This will allow the public to view the location of the snow plows within the last three hours of the day. The public web site prototype allows the user to zoom in and out in a simple viewer. This is user friendly interface and does not require any additional software to be downloaded to view. Providing the location of the snow plow trucks within the last three hours, allows the public to make more informed decisions before traveling in a winter storm.

Figure 14. County Internet Application



Benefits and Future Uses

The benefit of the visual and statistical data that is complied allows the MCDOT staff to make informed decisions. The visual map display allows the viewer to track where the snow plow has been, the pavement temperature, speed, the amount of salt applied, etc. Having an understanding of the pavement temperature allows the staff to adjust the application of salt to the road conditions. Not only can a visual reference be seen, but a statistical calculation can be created as well. This allows better efficiency in the application of salt brine and in the end will save in cost.

MCDOT continues to improve operations with technology. In addition to providing maps of the routes traveled by the snow plows, the operational statistics collected by the computer controlled dispensers are able to be displayed on maps to evaluate operations beyond time and location variables.

In the future, it is hoped that regular evaluation of snow plow operations using this data will continue to provide a tool to use resources more efficiently, assist in management of operations, and increase safety with having a better understanding of the roadways.

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