Final Report (SPR Project 90-00-RB10-012) on the Maintenance Asset Management Project Phase II

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Final Report on the
Maintenance Asset Management Project
Phase II

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Shawn Blaesing-Thompson, GISP
Maintenance GIS Coordinator, Iowa Department of Transportation

Matthew Haubrich
Asset Manager, Iowa Department of Transportation

William Schuman
Managing Partner, Transcend Spatial Solutions

Iowa Department of Transportation
Office of Maintenance
800 Lincoln Way
Ames, Iowa 50014
Tel: 515-239-1971
Fax: 515-239-1005
Email: shawn.blaesing-thompson@dot.iowa.gov
Matthew.haubrich@dot.iowa.gov
bschuman@transcendspatial.com

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Shawn Blaesing-Thompson, Matthew Haubrich, William Schuman

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16 Abstract

This project resulted in the development of a proof of concept for a features inventory process to be used by field staff. The resulting concept is adaptable for different asset classes (e.g. culverts, guardrail, signs) and able to leverage existing DOT resources such as the videolog and LRS and our current technology platforms including Oracle and our GIS web infrastructure. The concept examined the feasibility of newly available technologies, such as mobile devices, while balancing ease of use in the field. Implementation and deployment costs were also important considerations in evaluating the success of the project. This project funds allowed the pilot to address the needs of two DOT districts. A report of findings was prepared, including recommendations for a full deployment of a field data collection.

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Asset Management, Maintenance, GIS, tablet, field inventory, inspections, assets, enterprise system, database, culverts, signs, guardrail, GPS, data collection

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EXPANDED ABSTRACT

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Iowa Department of Transportation (IA DOT) is finalizing research to streamline field inventory/inspection of culverts by Maintenance and Construction staff while maximizing the use of tablet technologies. The project began in 2011 to develop some new best practices for field staff to assist in the inventory, inspection and maintenance of assets along the roadway. The team has spent the past year working through the complexities of identifying the most appropriate tablet hardware for field data collection. A small scale deployment of tablets occurred in spring of 2013 to collect several safety related assets (culverts, signs, guardrail, and incidents). Data can be collected in disconnected or connected modes and there is an associated desktop environment where data can be viewed and queried after being synced into the master database. The development of a deployment plan and related workflow processes are underway; which will eventually feed information into IA DOTs larger asset management system and make the information available for decision making. The team is also working with the IA DOT Design Office on Computer Aided Drafting (CAD) data processing and the IA DOT Construction office with a new digital As-Built plan process to leverage the complete data life-cycle so information can be developed once and leveraged by the Maintenance staff farther along in the process.

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PROBLEM IDENTIFICATION

The Iowa Department of Transportation (IA DOT) has a need to streamline field inventory/inspection of assets while maximizing the use of new technologies. Currently, the field staff uses disparate methods for collecting and managing culvert inspection information. Often, information is gathered using paper documents and redundant data entry. The districts lack consistent protocols for how location information is collected and stored, making it problematic to consistently map and analyze statewide information using GIS or CAD software. In addition, it is difficult or impossible to use existing data in a spatially enabled enterprise data system to answer asset management questions. It is also recognized that better location information is available from the computer aided design (CAD) data and work is being done to leverage this information for use in the field.

PROJECT SCOPE

The goal of the research project is to standardize workflows, develop a potential enterprise database model, and identify technology that will make it easier and more streamlined to collect and maintain information about assets found in the field. It is our expectation that any system developed will be adaptable for multiple assets, easy to use for field staff, deployable across all districts, and readily tied into enterprise systems already in place. Several small scale field trials took place and recommendations for future implementation have been identified. The project also looked at collecting asset information throughout the life cycle of the asset (design through to maintenance) with most of the focus on field data collection.

DETAILED PROJECT DESCRIPTION

The first phase of the research project focused on several areas of interest. These include:

- A technology review of smart phones, handheld GPS units, laptop, and tablet hardware.
- A detailed review of tablet options
- A look at life-cycle process options
- And, tablet development of a prototype field data collection application.

The second phase of the project focused on additional areas of interest. These include:

- A technology review of existing and emerging tablet technologies.
- Field test of a series of mifi units from different vendors
- Meeting with offices within the division to identify multiple field uses for tablets
- Development of several groups to look at the data life-cycle process at different points in the workflow.
- And field testing of several tablet hardware using prototype application to collect several different features.

The rest of this paper will detail out our findings in these areas of interest as well as a recommendation for future enterprise-level deployment.

TECHNOLOGY REVIEW

Migrating to Tablets

At the start of the project, the project team had a list of criteria for our hardware evaluation. We expected to find that some hardware worked better, but all had to meet these minimum expectations to be considered for deployment. The evaluation criteria included, but are not limited to:

- Good screen visibility in outdoor situations,
- Hardware field durability (acceptable to use in rain, dirt, truck situations)
- Large screen size (7" or larger without being too large to carry easily in the field), yet reasonable size/weight
- Reasonably priced (with the idea that 200 or more tablets will be deployed)
- Flexibility of the operating system (compatibly with major platforms such as Android, Apple, and Windows operating systems to follow any direction preferred by IT)
- Ability for Iowa DOT computer security measures to be implemented
- Built in camera and microphone capabilities
- Touch screen rather than a stylus keypad to operate
- Ability to interact with accessories such as Bluetooth GPS devices
- Long battery life (6 hours or longer was deemed acceptable)
- Option to use 3/4G cellular service
- Wi-Fi enabled.

Tablet options

Due to the wide variety of tablets available on the market, the research team felt it would be prudent to review the specifications for a number of tablet devices. This includes tablets that run with various operating systems including Google Android, Microsoft Windows, and Apple iOS.

For the most part the tablets we reviewed are all touch based, however, several used a stylus. We used the same criteria (above) for ranking each tablet and then applied a weighting system based on prioritization of these criteria. In the 2012 article "A Brave New Rugged World", the top priority features for devices is ruggedness, integrated wireless, touch screen display, antiglare screen and built in cameras which were all high priority items for our device(*1*). The article also recommends looking at the true cost of failure should we opt for a lower quality device over a more rugged one if it goes offline in the middle of a field day. While we expect to have some downtime due to device issues, we feel the cost of the rugged devices is not worth that safety net due to the intended use of these devices.

The research team originally felt that price would be a big factor if we were to go with a ruggedized device. Most of the consumer-grade tablets on the market are in the $400 - $600 range, however, the screen visibility on most of these inexpensive units made them difficult to use outdoors. We were able to overcome this with several units using a matte anti-glare screen cover. Other required features include Wi-Fi, a touch screen, and a built in rear camera which eliminated many of the Windows based models.

We started our device review by working through the December 2011 article "Tackling the Tablet Conundrum: Which One is Right For You?" to get a handle on the highest rated lower cost tablets.(*2*) The two highest-rated tablets, based on our criteria and prioritization, were the ruggedized Panasonic Toughpad A1 and the ix104C5 DMSR . Ruggedized Android tablets are not yet common on the market and run about three times the initial cost of basic consumer-grade tablets; however they are still about one third the cost of a heavy-duty ruggedized tablet PC. The rugged PC like Xplore (ix104C5) DMSR, which is being used by PennDOT for their bridge inventory and inspection process (*3*), run windows, weigh around 5-6lbs and cost around $3500 per device. When we showed some of the field staff this unit they felt the weight and cost negated the ruggedness and application flexibility of the device.

In Phase I, the research team met with the Iowa DOT Information Technology (IT) Division management team to talk through the future of tablets within the department and to establish whether there was any preference with respect to platform or operating system. During the discussions it became clear that the IT Division would support any of the operating systems under evaluation. The IT Division has a solution to manage the security of mobile devices, so that has become less of an issue than was originally anticipated. IT also indicated they would prefer a more ruggedized device be purchased under the assumption that these kinds of hardware can serve multiple functions and will have a longer lifespan than the consumer-grade devices.

The research team continued to work with IT through testing during Phase II. They have been an integral part of the process as we troubleshoot tablets, device management applications, and Wi-Fi units and move to statewide deployment.

Mifi Units

The research team worked with IT to field test several mifi (portable Wi-Fi) units. The first unit is a Verizon 3g unit. This device worked fine in areas where Verizon had good coverage in the state of Iowa; however, at this time we have several districts which are in poor coverage areas. The second unit tested was a US Cellular Samsung 4g/3g device. During field tests it was found that the device has connection hiccups when transitioning from a 4g to a 3g area, however, the coverage for US Cellular within in the state is more complete. These first two units are a good size for field tests as they are approximately credit card size and about a ¼” thick. The last unit tested, and ultimately the unit we recommend for future deployment, is a US Cellular 4g ZTE unit. It has a function to set the unit at 3g, 4g, or whichever is available in the area. It is twice the size of the other two mifi and slightly more complicated to use, however, these will be preconfigured for the field staff to allow them to only have to keep the devices charged and switched on to use them with the tablets in the field.

TABLET FIELD TESTS

During Phase II of the research project we field tested several devices with ten inch screens including the ASUS Infinity Transformer (*4*) which has an Android operating system and docking keyboard. The Panasonic Toughpad A1 (*5*), also an android system, was also field tested as well as the Apple IPad Gen2 and Gen4(*6*). Our contractor that assisted with the prototype application development recommended an anti-glare screen shield by Great Shield which makes tablets with high resolution screens more visible in partial to full sunlight in the field. The IPads were ruggedized using an Otterbox case and the ASUS units were ruggedized using a thick silicon cover. Both of these cases protect the devices from falls and lite water however neither case will protect the device from rugged field usage or weather conditions (extreme heat, cold or wetness).

The Panasonic Toughpad comes ruggedized, includes an antiglare screen, and can handle being dropped or wet. We expected this device, while twice the cost of the others, and would be ideal for field situations. Eight Panasonic Toughpad A1s were initially distributed to the field in March of 2013. The field likes the rugged nature of these devices. It was found they worked best using the provided stylus due to the screen cover thickness, although they also worked using finger touch. Several issues were identified with the Toughpads, and the first was limited ability to fully install applications from our vendor and the Google App store, which caused applications to force close or not work correctly. The second is the lack of ability to stay connected to the mifi units or internal office Wi-Fi. We tried both of the US Cellular Mifi with these devices, but have had limited success maintaining connectivity which has made it difficult to synch the devices to the cloud based storage database the data collection prototype uses.

We replaced five of the Toughpads with the ASUS units and this solved the connectivity issues. The ASUS unit provides the same software functionality with our prototype application, so there was minimal negative feedback aside from concerns about the rugged capabilities of the device. The field liked the concept of having a docking keyboard available to do more detailed data entry with the device, however, the cover has to be partially removed to access the docking port.

There were some issues with screen size of the Toughpads and IPads using our prototype application. The Motorola Xoom we used for testing in phase I and the ASUS units run 8.5 x 5 inches in screen size, while the other two run 8 x 6 inches. Any application that has size and orientation hard coded makes it difficult to install from one device type to another. Any application developed in the future should account for various screen sizes and rotation capabilities from landscape to portrait.

Asset Collection Tool and Tablet Testing

Upon a quick overview of the Highway Division instructional memorandums (IMs); which are recommendations developed by management and field staff to identify best practices for Maintenance field staff, we found at least eight roadway features for which they are responsible for doing regular inspection. For the purpose of our field tests, we worked with Transcend Spatial Solutions (Transcend) to further develop the Mobile Asset Verification and Road Inventory Collection (MAVRIC^{TM}) prototype application, and focused on a culvert module, as well as development of sign, guardrail, and incident data collection modules. An interactive web module, called Road Analyzer also developed by Transcend, can be used for generating reports and view information collected after synching the data is also available.

Screen captures for these modules are included in Figures 1-7. The MAVRIC interface has three main components, a straight-line diagram, asset buttons, and in the bottom window users can view either attributes about the road network or a basemap. Once the asset button is selected, the module for that asset opens up and shows a series of data driven forms. Many of the buttons in the forms, as seen in figures 1-7, have lists which the user can pick from to minimize the need for additional typing. The assets have a location/inventory component with the where and what information, as well as an inspection component where information can be collected about the condition of the feature. Once a new feature is collected, it will show up in the straight line diagram. Features can also be selected from the straight-line diagram and edited. Every module also has a component that allows photos, audio, and video to be stored with the asset record.

Efforts we focused on for additional development within the prototype include troubleshooting connectivity. We wanted the field staff to be able to collect data in the field without needing a network connection. This required preloading the road network data onto the devices specific to the areas the tablets were to be used in as well as doing some staff training on how to access the preloaded data.

Another area of focus in phase II was how to deal with network connectivity. While the field was able to work with a mifi connection in most cases, there are still some areas of the state which have limited cellular coverage so connectivity would come and go in these areas. Another issue was related to field staff synching at the same time. During the spring and summer schedules for the field staff have them all getting to the office around the same time so we had cases where multiple groups were hitting the database to do updates at the same time. We had to develop some processes to accommodate this situation and alert the field staff if their data upload was not successful.

Some culvert and sign data, which had been collected previously, was loaded into the MAVRIC data schema which is housed in the Cloud. In some cases, the legacy location was so incorrect, so a "Move to Current Location" tool was available to allow field staff to adjust the locations of culverts and signs which had slightly incorrect latitudes and longitudes.

During the field test process, a few protocols had to be developed for photo collection. First, we reduced the size of the photos being captured and saved on each device to allow for more streamlined synching. Then we identified what kind of photos should be collected in the inventory versus inspection components of the application.

The research team has been working closely with the IT staff to do tablet configuration. One of the first areas of focus was establishing accounts for the devices which allowed managing applications from the Google Play store. Two generic email accounts were generated, one for Gmail and one internal to the DOT, to be shared across the devices. The next step was to secure the devices should they become lost. The first software we tested is the McAfee Enterprise Mobility Management (EMM) (*7*) which works on both the Android and iOS operating systems. It provides a layer of security which allows the DOT IT staff to wipe the device and lock it down should it not be in IA DOT possession. Ultimately, IA DOT selected AirWatch (*8*) for wide spread deployment; which provides similar functionality to the McAfee EMM software. However, AirWatch allows a tablet to be checked out of a pool and then the device is automatically configured with DOT email and assigned applications specific to the user.

Additionally, IA DOT is working through leveraging DOT hosted webservices, which are spatial data in map form for the web, specifically the DOT basemaps. These are currently pushed out to the internet and can be consumed by websites and application for those who have the location path. There were some issues with the server security settings which we had to overcome to make the maps available on the devices. We now have a tool which allows the basemaps to be loaded on the device for a specific region or to be interacted with over the network. The basemaps have several zoom levels and highlights the road where data collection with the tablet is active.

Twelve field personnel from around the state testing the tablets and the MAVRIC application. Two group trainings were held, a high level training document was installed on each device, and the deployment team did a lot of one-on-one and phone support over the four months the devices were deployed. Overall the field staff was very patient as we worked to trouble shoot issues that came up, but the field staff is encourage by the possibilities of being able to collect information in the field where it is entered once, has images included, and then is available to many as soon as the device data is synched up.

Here is a quote from our District 3 staff, "I think it is definitely a great tool with a lot of potential. I'm looking forward to working with it some more because I think we have just touched the tip of the iceberg on this technology. This will make our jobs easier to document information, to find information and to fix things out on the system." Additional enhancement the field recommended for future application development includes additional assets such as lighting and more detail for subdrains; as well as a way to document the culvert inlet versus outlet issues. They would like to be able to put comments with the photos as they are taken. They would like a way to better see multiple assets like culverts or signs where there might be a group of them within a few feet of each other. They would like one device with access to edit and interact with multiple feature types.

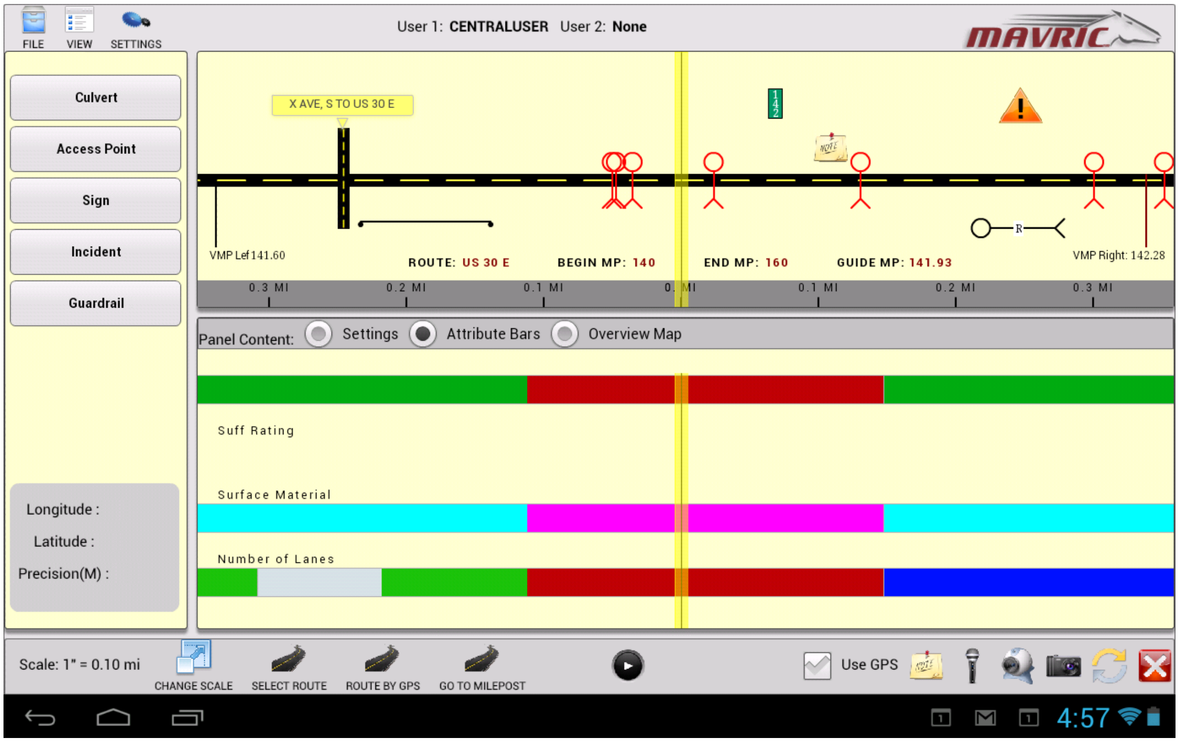

Figure 1a

Figure 1b

Figure 1a and 1b – Examples of the MAVRIC main screen with data collection buttons per asset on the left, a roadway straight line diagram above, and asset attribute bars below (Fig 3a) or the IA DOT web map (Fig 3b). Culverts are shown by their type and location. The circle denotes a round culvert (vs. an arch or box) and the horizontal culver with the "R" denotes a culvert on a ramp. A guardrail (horizontal like with dots below the ends) and incident (orange exclamation point) are also shown.

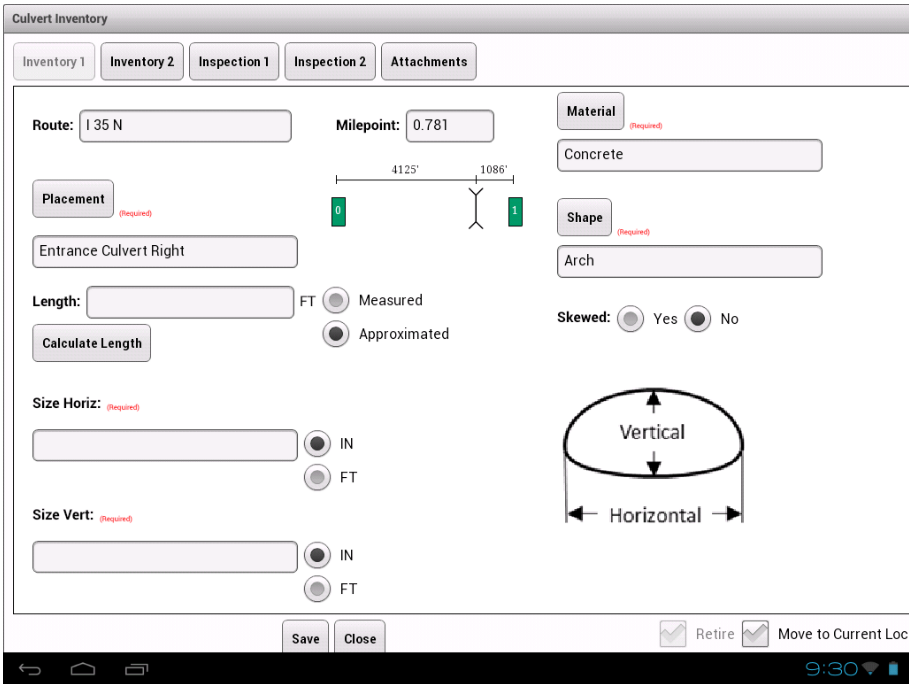

Figure 2 – MAVRIC culvert inventory first screen. Each button has a list of choices to choose from to reduce the need to type information in.

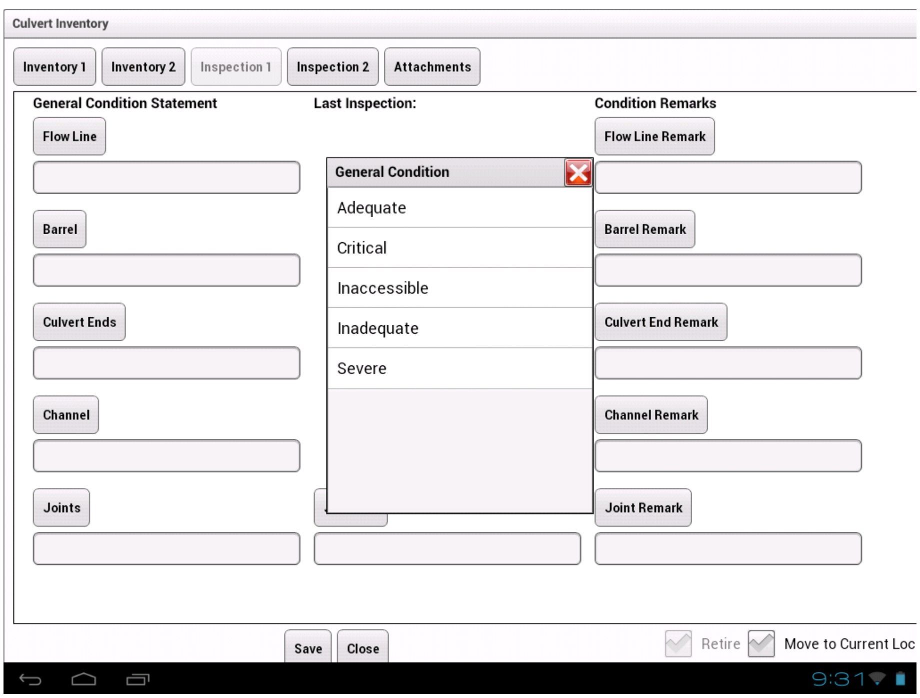

Figure 3 – MAVRIC culvert inspection first screen with a pick list example.

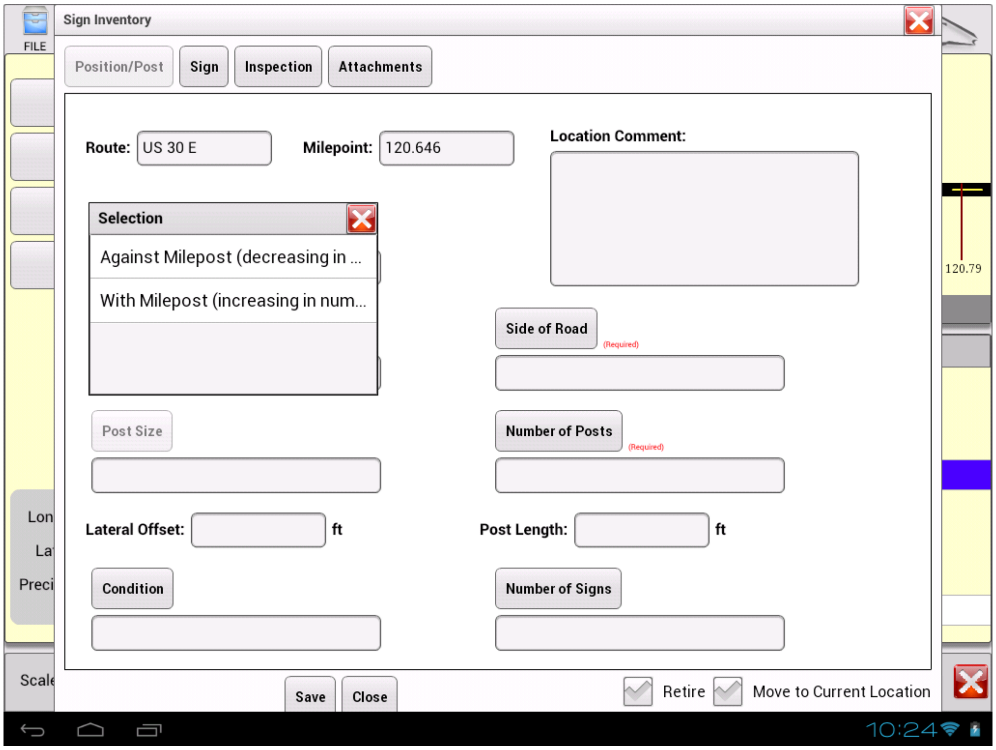

Figure 4 – MAVRIC sign inventory post screen with a sample pick list.

Figure 5 – MAVRIC sign inventory, sign designation screen with images available when assigning a sign type.

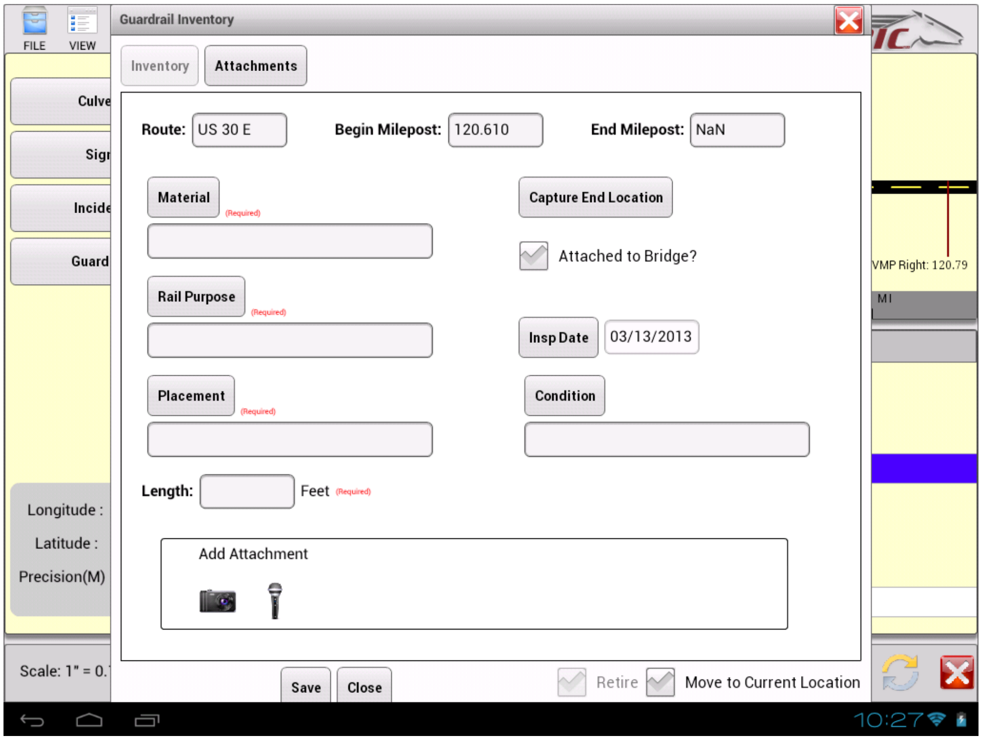

Figure 6 – MAVRIC guardrail inventory and inspection prototype

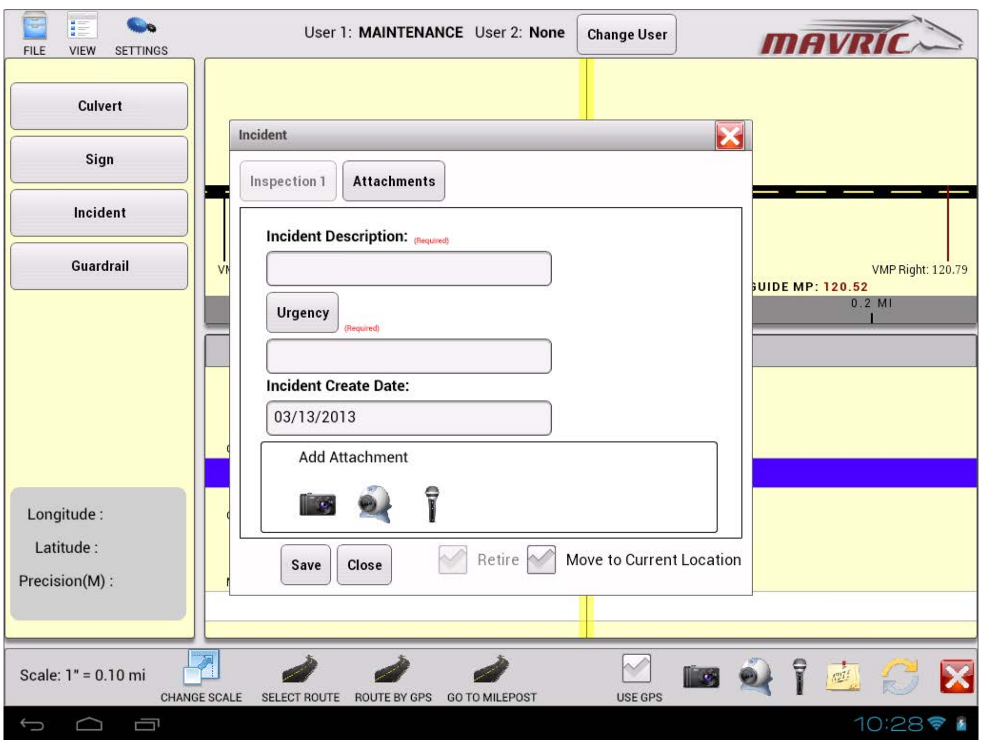

Figure 7 – MAVRIC incident interface allows a user to log anything unusual they come across while on the road network.

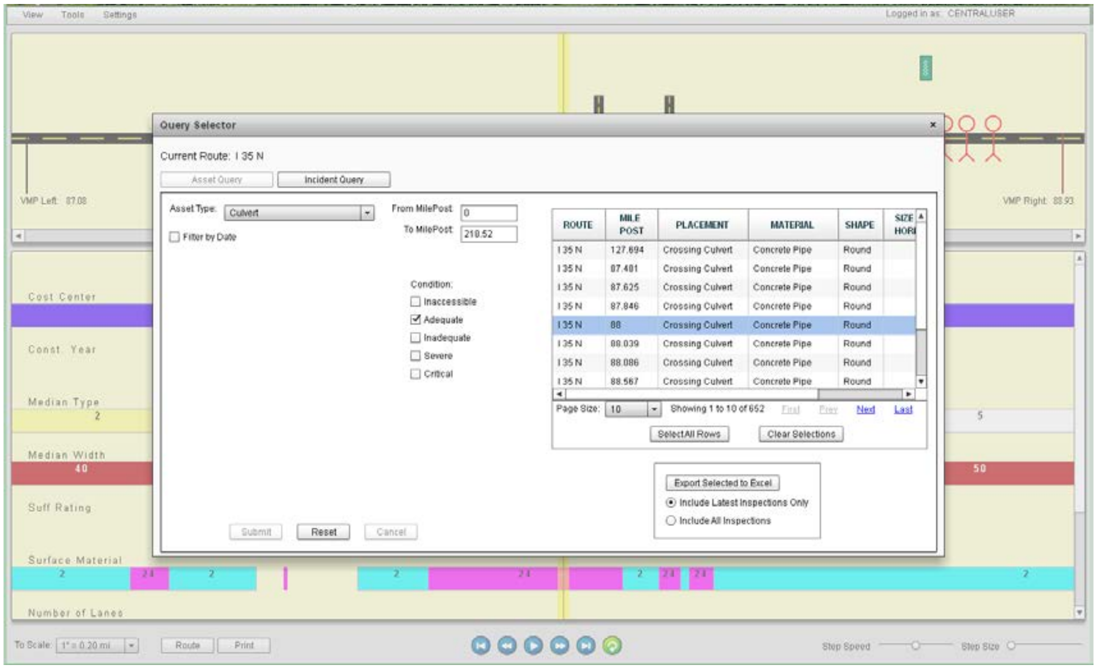

Figure 8 – Road Analyzer web application reporting query screen.

LIFE CYCLE DATA DEVELOPMENT

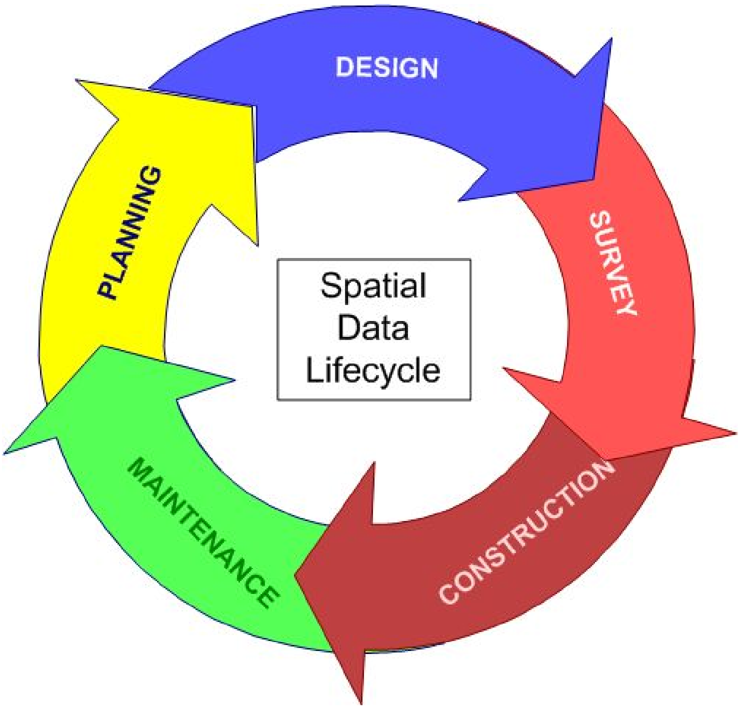

Figure 9 – DOT spatial data lifecycle flow diagram

While the tablet project has been focused on the inventory and inspection of field related features, an offshoot effort is underway to look at leveraging information about assets earlier in the data life cycle (Figure 9). More work needs to be done within the DOT to allow data to flow from one office to the next via enterprise data storage systems. For example, several offices were interested in knowing what culverts exist on our system of a certain type due to pending litigation, and there were questions about styles of culverts have a higher rate of failure so computer aided design files (CAD) design staff can make better design specifications for future builds. As a result of these conversations, it was clear to the team any data the Maintenance staff collects can be beneficial above and beyond maintenance operations. Maintenance staff is not the first group in the data lifecycle to collect feature location data so conversations are being had with the Design and Construction offices to capture that data earlier.

Working with staff in the IA DOT Office of Design we found that CAD files, which are developed using survey grade information, give us the best first glance at where features occur along the road network. Besides locating existing structures, they show the locations of future structures and gather tabular information about these features. For example, during a culvert design, they survey existing culverts, draw in new alignments or additions to those culverts and load an access database related to that culvert - capturing size, location, material type, length, etc.

Throughout the construction process information is often gathered again within the As-Built development. Through continued discussions with several of the offices within the IA DOT highway division, modifications to existing workflows are being identified to extract information from CAD files into a centralized database. A technical group has been established to look at the design side of the workflow so survey grade spatial information can be pulled into an enterprise spatial database. A pilot is under way to look at options for assigning some of the tabular information which would be relevant throughout a feature's lifecycle to the same feature in the CAD design file.

A second group was established to look at the As-Built part of the process. Currently, the Resident Construction Engineers (RCE) overseeing the construction project use a PDF version of the plan sheets to mark up any As-Built changes that occur during the construction process. IA DOT has two pilots currently underway to look at the feasibility of doing survey during and after construction to gather a spatial, digital As-Built data set for specific features. The plan for a Phase III pilot is to develop a bid item for a digital As-Built derived from the IA DOT CAD plan sheets and supplemented with information gathered through survey during and after construction. This information will be fed into the enterprise asset management databases which are currently under development.

IDEAS FOR FUTURE FOCUS

A Maintenance Management System

One of the issues that came up early in conversations with the field staff is data availability and tools to assist with the decision making process. Conversations are being had to identify what a Maintenance Management System, which we can feed this information into, might look like and how management might use that information for long range planning.

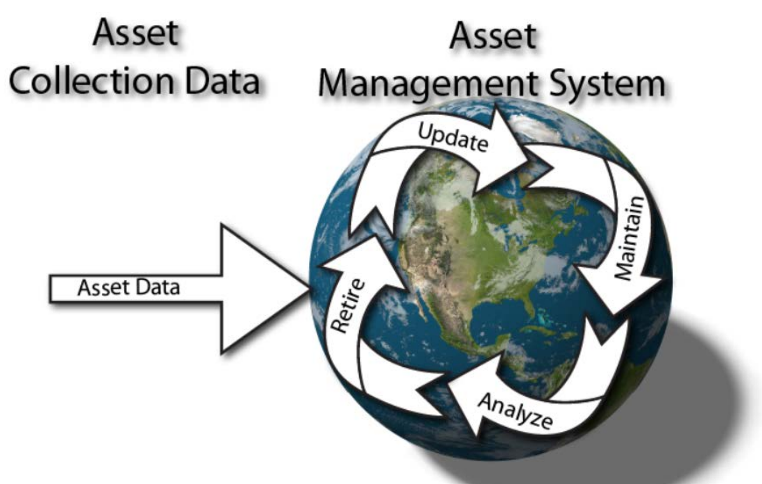

Figure 10 – Working towards a system which allows us to maintain information over time and use it to leverage in our decision making process.

Purchasing Tablets

The research team was asked to make a recommendation for tablet purchase in the spring of 2013. The team recommended the ASUS unit as opposed to the Panasonic due to the difficulties and costs related to the Panasonic Units. The team found that a good anti-glare screen made the IPad a viable option as well. It was decided by management to purchase 120 IPad tablets for field deployment in the fall of 2013. While the primary use for these devices is for road condition reporting they will also be available for the field to use as inspection and inventory devices outside of severe weather events.

New Technology

Through the process of testing MAVRIC several other technology options became available. The first is Fulcrum which is a fee for service spatial data collection tool. It allows us to "easily create, deploy and manage field data collection apps for iPad and Android." (*9*) We have purchased 25 seats for testing of a culvert inventory and inspection form for fall 2013.

Also, now available is the ArcGIS Mobile version 10.2 (*10*). ArcGIS mobile leverages our existing webservice infrastructure along with the ArcGIS Online licensing we are in the process of acquiring. With the new version disconnected data collection using tablets is possible. There is some server infrastructure and data development that needs to happen within the IA DOT before this technology can be tested.

The DOT also has a software package called Dundas Dashboard (*11*) which data to be compiled once it is collected to push out reports and do some basic analysis. The final technology option is the use of an intranet webportal which can consume data as webservices and field staff can interact with the data through a web browser.

CONCLUSIONS

This research has enabled the team to evaluate tablet and mifi hardware, a variety of application options and do a field test with live data collection. The feedback from management and the field teams has been positive and we are working towards a final deployment solution in hopes of making something available for the spring data collection season.

The research team still needs to do more work with the field staff to look at workflow processes for collecting and managing the information, and development of reporting tools. We need to finalize what our data collection solution will be which may include going to RFP. We plan to spend some time rendering data as a webservices and potentially developing some simple reports for management based on the asset condition data collected.

Whatever our final deployment is, there is an expectation for an enterprise deployment of a system which will standardize a process for all of the field staff responsible for inventory and inspection of designated assets. This will also centralize the data storage process which allows data to be fed into a feature Maintenance Management System and become part of the agency wide asset management system.

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FIGURES

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Figure 2 – MAVRIC culvert inventory first screen. Each button has a list of choices to choose from to reduce the need to type information in.

Figure 3 – MAVRIC culvert inspection first screen with a pick list example.

Figure 4 – MAVRIC sign inventory post screen with a sample pick list.

Figure 5 – MAVRIC sign inventory, sign designation screen with images available when assigning a sign type.

Figure 6 – MAVRIC incident interface allows a user to log anything unusual they come across while on the road network.

Figure 7 – Road Analyzer web application reporting query screen.

Figure 8 – DOT spatial data lifecycle flow diagram

Figure 9 – Working towards a system which allows us to maintain information over time and use it to leverage in our decision making process.