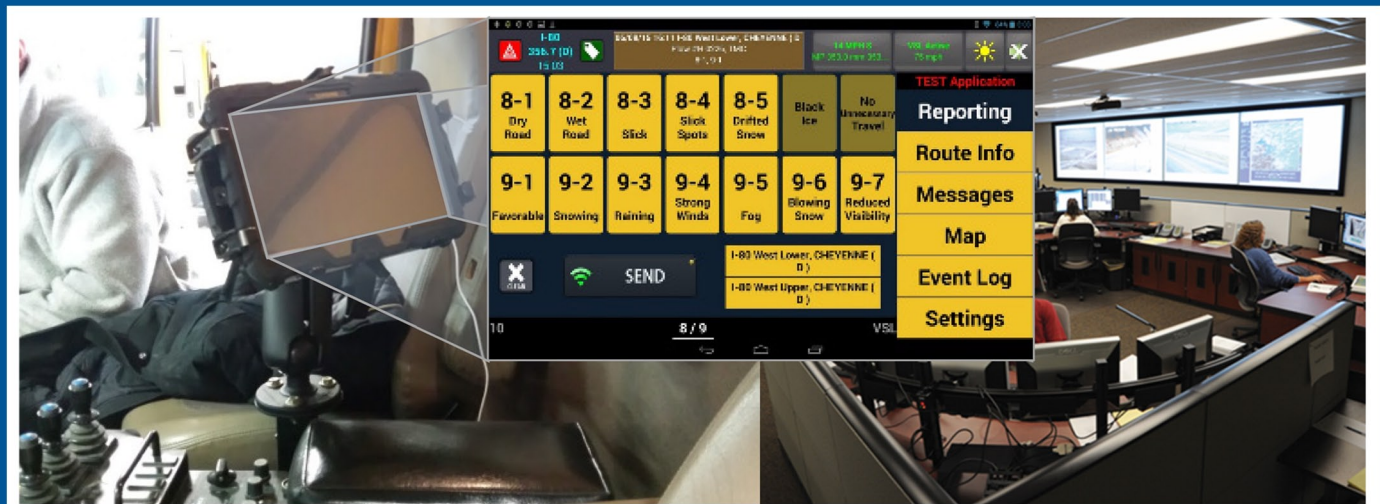


Wyoming Department of Transportation (WYDOT) Road Condition Reporting Application for Weather Responsive Traffic Management

Final Report — October 2015



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16. Abstract Federal Highway Administration's (FHWA) Road Weather Management Program (RWMP) strives to promote the development and implementation of cutting-edge techniques for maintaining safety, mobility, and productivity of roadways during adverse weather conditions. A particular Weather Responsive Traffic Management (WRTM) strategy developed and described in this report involves mobile data collection and reporting system in Wyoming for road weather information during weather events. A concept of operations and an evaluation plan were developed and utilized in the project. The objectives of the system were to improve the efficiency of road condition reporting and actions taken in the Traffic Management Center (TMC), the timeliness of updated traveler information, and the situational awareness of field maintenance staff. This report documents the implementation and evaluation of the system. Overall, the evaluations indicate improved effectiveness and efficiency of road condition reporting and traffic management center activities during weather events. Furthermore, improvements in the TMC data management systems, frequency of road reports, and field information accuracy were also noted. The report contains the description, development, and implementation of the system; the evaluation approach and results; and conclusions, lessons learned, and recommendations based on the evaluation results.					
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Executive Summary

Weather Responsive Traffic Management (WRTM) involves implementation of traffic advisory, control, and treatment strategies in direct response to anticipated or occurring roadway and visibility issues that result from forecasted or deteriorating weather conditions. WRTM also includes providing proactive advisories and control strategies based on forecasted weather conditions, and not just the after effects of those conditions. One of the primary focus areas of the Federal Highway Administration's (FHWA) Road Weather Management Program (RWMP) has been to encourage the development and implementation of WRTM strategies. Specifically, this report describes the system development and implementation, and summarizes the evaluation of the Wyoming DOT Road Condition Reporting Application.

Initial Implementation of the Wyoming Road Condition Reporting Application

The objectives of the Wyoming Road Condition Reporting Application Project are:

1. Improve the efficiency of road condition reporting by maintenance staff
2. Improve the efficiency of the Transportation Management Center (TMC) operations in responding to the reported road conditions
3. Improve the timeliness of updated traveler information
4. Improve the situational awareness of maintenance staff in the field regarding road weather conditions

The initial WRTM project implementation included the development of a new software application (the "App") to improve the way maintenance staff report road conditions from the field. The App is used by WYDOT maintenance personnel to report road weather information to the TMC, recommend variable speed limit changes, report snow performance measures, and report a number of different traffic incidents including crashes and road hazards. In addition, the App is used to share information with maintenance employees, including the road conditions that are reported to the public, variable speed limit information, weather information, messages posted on dynamic message signs, and map-based asset location information. It is also used to send and receive messages similar to email. This application was built to run on a tablet computer ("tablet") and utilizes Wyoming's extensive statewide communication system backbone called WyoLink.

The software was initially implemented on 20 tablets used mostly in WYDOT plow trucks on I-80 and portions of I-25 to report road conditions during the 2014-2015 winter season. The implementation also included changes to data management systems in the TMC to accept road condition reports from the tablets and assist TMC operators in performing their duties.

Evaluation Findings

The initial implementation of the road condition reporting application was evaluated to assess its effectiveness and potential to improve Wyoming's road condition reporting and traffic management activities. The evaluation focused on four hypotheses associated with the objectives of the system described above. Table ES-1 shows the four hypotheses and summary of the primary results associated with each hypothesis.

Table ES-1. Wyoming WRTM Project Evaluation Hypotheses and Summary of Results

Hypothesis	Summary of Results
1: The application will improve efficiency of condition reporting by maintenance employees and TMC operators	<ul style="list-style-type: none"> On average, the number of road reports submitted using the App doubled compared with the number of reports using the standard method. On average, the number of variable speed limit (VSL) change requests received in the TMC using the App was 3 times the number of reports using the standard method. The App allows for timelier submission of road reports, with 91 percent of maintenance staff reported having to wait to use the radio to make their road reports. All maintenance staff survey respondents answered "yes" to the question "Do you feel this new technology is useful in your operations?" A significant amount of time is saved when the App is used to automatically submit road reports to the TMC and not having to log the reports or update the traveler information systems. 89 percent of TMC operator respondents said that the agency is better off with the App. 82 percent of maintenance staff survey respondents indicated that the App was either very easy or easy to use.
2: The application will improve traffic management capabilities during weather events.	<ul style="list-style-type: none"> The App is easier to use than the radio to provide the TMC with recommended VSL and dynamic message sign (DMS) changes. More VSL and DMS message changes were requested using the App. The information provided from field maintenance staff associated with the VSL and DMS changes is more accurate when submitted using the App, which allows the operators to act more quickly and with more confidence. 78 percent of the operators surveyed indicated that it was easier to know which DMS to update when the request came via the App The time taken by operators to update VSL or DMS messages was the same regardless of the request transmission type.
3: The application will improve the timeliness of condition reporting updates to the public.	<ul style="list-style-type: none"> Twice as many road condition reports were submitted by field maintenance personnel using the App compared to those submitted by the standard method. This frequency increase implies an improvement in timeliness of reports to the public. 64 percent of maintenance staff survey respondents stated that they were able to send more reports and field codes using the App when compared to using the standard method, and that it took them less time to submit a road report using the App.
4: The application will improve situational awareness of maintenance employees.	<ul style="list-style-type: none"> 73 percent of maintenance staff survey respondents said they feel more informed about road conditions within their area of operation. 100 percent said they found the milepost location useful.

Source: Battelle/McFarland Management

Conclusions

The use of the Wyoming DOT Road Condition Reporting Application improves the effectiveness and efficiency of road condition reporting and traffic management center activities during weather events. Based on road reports including storm days and non-storm days from January 2014 to December 2014, WYDOT estimates that using the App can result in more than one person-year of time savings. In addition to the use of the App, the improvements in the TMC data management systems also contributed significantly to this finding. Increased frequency of road report submission directly improves the timeliness and accuracy of traveler information provided to the motorists. Additionally, accuracy of information from the field was substantially improved – specifically road condition reports, VSL and DMS change requests, and location of incident reporting.

Much was learned during this initial implementation and WYDOT is planning to incorporate system enhancements to further refine and expand the system that was tested and evaluated under this implementation. WYDOT intends to expand the installation of the App in as many as 150 vehicles for the next winter season. Additionally, further development will be completed to integrate the App into existing systems. WYDOT also intends to take advantage of the functionality of the tablet computers by developing web apps to create electronic versions of paper forms currently used in maintenance operations, including vehicle inspection and repair requests.

Chapter 1 – Introduction

Weather Responsive Traffic Management (WRTM) involves application of traffic advisory, control, and treatment strategies in direct response to existing or anticipated or occurring roadway and visibility issues that result from forecasted or deteriorating weather conditions. WRTM includes providing proactive advisories and control strategies based on forecasted weather conditions, not just the impacts of those conditions. One of the primary focus areas of the Federal Highway Administration's (FHWA) Road Weather Management Program (RWMP) has been to encourage the development and implementation of WRTM strategies.

In 2011, the RWMP initiated a project to document existing strategies for WRTM, identify improvements to the strategies, and develop implementable Concepts of Operations for the improved strategies.¹

This report describes the system development and implementation and summarizes evaluation results of a recently completed project in Wyoming DOT to develop Road Condition Reporting Application for WRTM.

1.1 Project Overview

The Wyoming WRTM Road Condition Reporting Application (hereinafter referred to as “App”) addresses both maintenance staff activities to report road conditions and TMC staff actions taken based on the reported information. TMC operator actions taken based on input from the field maintenance staff could include updating the traveler information system, changing variable speed limits, changing message signs, or closing roads. It is important to note that all functions of the App were previously performed manually by the WYDOT staff, and the new App allows these processes to be automated using computer systems.

The primary focus was on the development of a new software application to improve the way maintenance staff report road conditions. The App was built to run on a tablet computer and utilized Wyoming's extensive statewide communication system backbone called WyoLink.

The WYDOT WRTM project is intended to improve:

- The efficiency of road condition reporting by maintenance staff
- The efficiency of TMC operations to take actions based on the road conditions reported
- The timeliness of updated traveler information
- The situational awareness of maintenance staff in the field regarding road weather conditions

¹ FHWA, Developments in Weather Responsive Traffic Management Strategies, June 2011, FHWA-JPO-11-086, available at http://ntl.bts.gov/lib/42000/42900/42965/wrtm_final_report_06302011.pdf

This initial project implementation included 20 tablets with the new software application pre-loaded, and the tablets were installed mostly in WYDOT plow trucks to report road conditions during the 2014-2015 winter season. These tablets were deployed in trucks serving in District 1 (Cheyenne) and District 3 (Laramie) and operating along I-80 and a portion of I-25. The implementation also included changes to data management systems in the TMC to accept the road condition reports from the tablets and assist TMC operators in performing their duties associated with this new implementation.

This report describes the system in detail and provides the evaluation results for this initial implementation.

1.2 Organization of the Report

The rest of the report includes the details of the Wyoming DOT road condition reporting system, as well as descriptions of the implementation, operations, and the evaluations conducted as part of this effort. The report is organized as follows:

- Chapter 2 describes WYDOT's road condition reporting system
- Chapter 3 describes the project development and implementation details
- Chapter 4 describes the evaluation approach
- Chapter 5 provides the results of the evaluation
- Chapter 6 summarizes the conclusions and lessons learned
- Chapter 7 summarizes the recommendations
- Appendix A includes the list of abbreviations and acronyms
- Appendix B includes the full concept of operations developed for this implementation
- Appendix C includes the complete evaluation plan for this implementation.

Chapter 2 – System Description

2.1 Existing WYDOT Systems

WYDOT's Transportation Management Center (TMC) serves as a central hub for all road condition reporting, maintenance dispatching, and Intelligent Transportation Systems (ITS) operations in the state of Wyoming. Prior to implementing the road condition reporting App in maintenance vehicles, WYDOT employees called in road condition reports to the TMC via cell phone or WyoLink, a statewide digital, trunked, VHF P-25 compliant public safety communications system designed to coordinate and integrate communications between state, local, and federal public safety agencies. TMC operators also received information through a task list system, known as the Transportation Reports and Action Console (TRAC), which allows external systems such as the Wyoming Highway Patrol's computer-aided dispatch (CAD) system to feed information to the TMC. The WYDOT TMC is shown in Figure 2-1 below.



Source: WYDOT

Figure 2-1. WYDOT Transportation Management Center

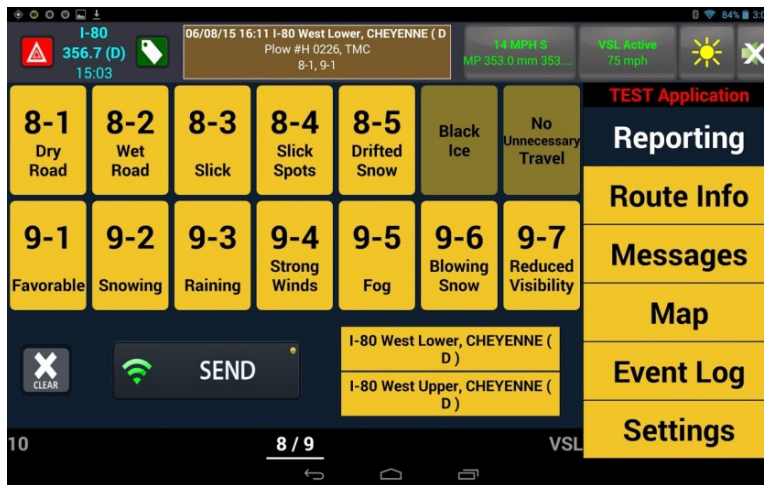
When TMC operators received reports via the radio or telephone, they would record the information into an electronic log. Information received via TRAC would not have to be logged manually by the operators because it is automatically logged by the TRAC system. Operators would then update roadside systems (DMS, VSLs, etc.). After all roadside systems were updated, TMC operators would update the pre-trip information system by using a road condition reporting system, known as the Wyoming Travel Information (WTI) system, to report road conditions through the agency's website, 511 telephone-based traveler information system, and the 511 Notify text and email push notification system. In some cases, especially when the TMC was tasked with coordinating a road closure event, information for the pre-trip information systems might not be updated for 10 or 20 minutes.

2.2 Road Condition Reporting System

The new App is used by WYDOT maintenance personnel to report the road weather information to the TMC, recommend variable speed limit changes, report snow performance measures, and report traffic incidents including crashes and road hazards. In addition, the App is used to share information with maintenance employees including the road conditions that are reported to the public, variable speed limit information, weather information, messages posted on dynamic message signs, and map-based asset location. It is also used to send and receive messages similar to email.

In order to minimize the on-going costs, WYDOT elected to forego monthly cellular costs for the App by deploying Wi-Fi hotspots and by using the low-speed data channel on the WyoLink statewide radio network. Thirteen *Ubiquiti* Wi-Fi hotspots with high-gain antennas, which cost approximately \$200 per site and provide coverage ranging from 0.25 miles to 1.25 miles, were deployed at sand piles, fuel sites, and other locations. The WyoLink radio network became critical to the success of this project because it has a low-speed data channel that provides excellent statewide coverage when compared to cellular availability. The WyoLink low-speed data channel is capable of sending and receiving all data to and from the App with the exception of larger data packets associated with the mapping functions of the system. Although Wi-Fi is the primary communication path, the App works seamlessly between Wi-Fi and WyoLink.

The App was designed with a status bar and multiple tabs. Figure 2-2 shows a screen shot of the App on the tablet. The status bar persists at the top of the screen regardless of what tab is being used and provides at-a-glance information and four easy selection buttons. A description of each in the order that they are presented on the screen are provided below:



Source: WYDOT

Figure 2-2. App Reporting Screen on the Tablet

Emergency – When selected, this button allows the maintenance employee to request immediate law enforcement assistance. A message is sent to the TMC that includes the location of the maintenance employee. TMC personnel are instructed to immediately call for a trooper to be dispatched to the site.

Location Info – This area of the status bar provides the user with very accurate indication of their current location down to the tenth of a mile. This is particularly useful during a blinding snowstorm.

GeoTag – The GeoTag button allows the user to quickly mark a location on the roadway while driving. The GeoTag can be used in conjunction with the Event Log to post-report an event. The details of the Event Log are described further down the list in this section.

Current Road Report – This area of the status bar allows the user to quickly see the road condition report for the section of the roadway they are currently working on. With a swipe to the left, the user can see the condition report for the previous section and with a swipe to the right, the user can see the current road condition report for the road section ahead of the user. In addition to conditions, it shows who created the last report and when it was created.

Wind Speed – Because winds cause significant issues in Wyoming, the status bar provides the wind speed at the nearest Road Weather Information System (RWIS) station.

VSL Info – If a maintenance employee is within a VSL zone, the status bar provides the employee with the current posted speed.

Brightness – A brightness adjustment button is provided so the maintenance employee can quickly adjust the brightness of the tablet for various lighting conditions.

Volume – The status bar volume button allows the user to quickly silence the App or adjust the volume from low or high.

The tabs run along the right side of the App and are organized as follows:

Reporting – This tab allows the maintenance employee to report road and atmospheric conditions, VSL recommendations, damage to roadside elements such as lighting, signs, guardrail; crashes and associated road blockage, animal carcasses and associated road blockage; livestock on or near the road, citizens in need of assistance, and snow performance measures. It also allows the user to request an ambulance or to provide detailed crash information.

Route Info – This tab allows the maintenance employee to retrieve information posted on DMS, RWIS and road condition reports posted on any road segment the operator selects.

Messages – Similar to email applications, this tab allows the maintenance employee to send and receive messages to other maintenance employees and the TMC. This feature is disabled when the vehicle is in motion as a safety precaution.

Map – The map tab allows the maintenance employee to see various WYDOT assets (road closure gates, DMS, RWIS, VSL signs) and the location of other maintenance vehicles. The user can choose a single button to switch the map to provide weather-related information such as a radar loop, wind speed vectors, and National Weather Service watches and warnings.

Event Log – The Event Log tab allows the maintenance employee to review all reports they have sent to the TMC and it allows them to post-report or update events. This can be very useful if the user is busy with more important tasks or new information is obtained which warrants an update to a report.

Settings – This tab can be used by the maintenance employee to customize the App for their needs. For example, the users can identify their department (crew) which will customize the names/contacts in the pick list of the Reporting sections.

2.3 Linkage to Other WYDOT Applications

It was critical to integrate the App with the WTI so that information from either system would not errantly overwrite information posted by the other system. To do this, a WTI Data Broker (WTIDB) was built to negotiate changes to the systems. Through the WTIDB interface, maintenance employees using the App are made aware of the changes made in the condition reporting system by the TMC operators, and similarly the TMC operators are made aware of the changes made by maintenance employees using the App.

WYDOT also needed a means to make the TMC aware of the App changes so that the TMC operators could update roadside systems, if warranted. To achieve this, the TRAC system was updated to inform TMC operators of items sent by the App, such as damage repairs, VSL recommendations, and road condition reports. Figure 2-3 shows a screen shot of the TRAC task list. When appropriate, the TRAC system also identifies roadside DMS, VSL, and Highway Advisory Radio (HAR) that may need to be updated. WYDOT further intends to modify the TRAC system with suggested problem, location, and action messages that TMC operators can use to update the HAR, VSL, and DMS. In time, this may allow for a more automated means of updating these roadside systems.

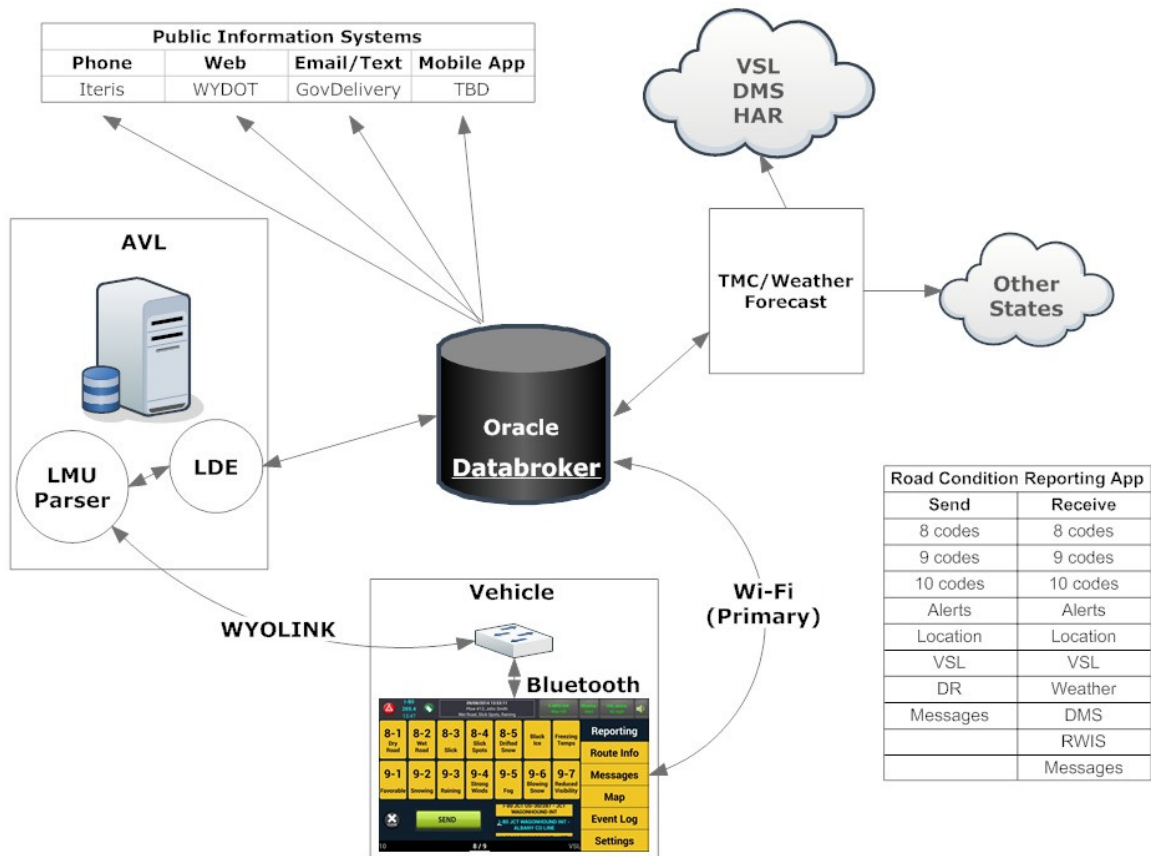
Transportation Reports and Action Console (development)										
TRAC Task List										
Create new Task Update Now Last updated 2015-03-16 13:29:38										
PK	Priority	Source	District	Description	Link	Created	Claimed	Completed	On Complete URL	
24023	Emergency	Plow	0	10-50: Crash Ambulance Requested at 41.620591/-106.241334 Plow license plate: H 0080, Operator ID: alragan, Dept: 1035	N/A	2015-03-16 10:17:32 by alragan	Claim 24023	Complete 24023	DELETE https://trac.trac_dev@wtidbd01.gisits.local:84	
24035	High	Plow	1	10-13: Cheyenne - I-80 West Upper Conditions: 8-1, 9-1 DMS: D000033 at I-80 WB 336.1 (Buford) Laramie Upper, D002833 at I-80 WB 341 (Remount), D000035 at I-80 WB 343.7 (Harriman) Cheyenne Upper, D000034 at I-80 EB 341.6 (Harriman) Cheyenne Lower Reported by plow: H 0080, operator ID: alragan	N/A	2015-03-16 10:14:30 by alragan	Claim 24035	Complete 24035	null	
24022	Medium	Plow	0	10-41: Operator on duty at 0.000000/0.000000 Plow license plate: H 0080, Operator ID: alragan, Dept: 1035	N/A	2015-03-16 10:14:08 by alragan	Claim 24022	Complete 24022	null	
24034	Medium	Plow	1	10-7: Out of service Cheyenne - I-25 North - Southbound at Reference Marker 12.5 Plow license plate: H 0241, Operator ID: sprettyman, Dept: 2033	N/A	2015-03-13 14:11:56 by sprettyman	Claim 24034	2015-03-16 07:33:05 by thr X	null	
24033	Medium	Plow	1	10-8: In service Cheyenne - I-25 North - Southbound at Reference Marker 12.5 Plow license plate: H 0241, Operator ID: sprettyman, Dept: 2033	N/A	2015-03-13 14:04:14 by sprettyman	Claim 24033	2015-03-16 07:33:07 by thr X	null	
24032	Medium	Plow	1	10-7: Out of service Cheyenne - I-25 North - Southbound at Reference Marker 12.5 Plow license plate: H 0241, Operator ID: sprettyman, Dept: 2033	N/A	2015-03-13 14:02:35 by sprettyman	Claim 24032	2015-03-16 07:33:09 by thr X	null	
24021	Medium	Plow	0	10-41: Operator on duty at 0.000000/0.000000 Plow license plate: H 0241, Operator ID: sprettyman, Dept: 2033	N/A	2015-03-13 13:47:47 by sprettyman	Claim 24021	2015-03-16 07:33:11 by thr X	null	
24020	Medium	Plow	0	10-42: Operator off duty at 41.165254/-104.844836 Plow license plate: H 0241, Operator ID:	N/A	2015-03-13 13:46:44	Claim 24020	2015-03-16 07:33:12 by thr X	null	

Source: WYDOT

Figure 2-3. TRAC Task List Screen Shot

2.4 Data Sources

The App sends and receives all information with a multi-node Oracle™ database that was built for high availability and which existed prior to the development of the App. As shown in Figure 2-4, the tablet computer communicates with the databases via Wi-Fi on a secure network. In the absence of Wi-Fi, the system is capable of seamlessly transitioning to the WyoLink radio network. The tablet connects with a Location Messaging Unit (LMU) via Bluetooth. The LMU is then capable of transmitting and receiving small data to a LMU parser. The parser communicates with the Location Data Engine (LDE), which communicates with a database that feeds information to the pre-trip information systems, and with the applications used by TMC operators.



Source: WYDOT

Figure 2-4. System Data Flow Diagram

2.5 Operational Process Changes Needed

The App has allowed maintenance employees to report road conditions when it is most convenient for them rather than when there is available time over the radio. WYDOT's radio system has a talk group for each of the State's five maintenance districts, and like most radio systems it only allows one person to speak at a time. This means during storm events when there are many operators starting or ending shifts and/or reporting conditions, there is a lot of radio activity and it is common for operators to have to wait for open air time before a condition is reported. For data communications/transmittal using the app, the radio system has a "store and forward" function. If the data channel is busy, the information is held until the line is open and then sent. This means that maintenance personnel are able to send reports when it is most convenient for them, regardless of how busy the radio system is. Survey results show all respondents, except one, were able to send a report using the App when they otherwise would have had to wait to make a report over the radio. Additionally, operators said that they might not send a condition report if the radio is too busy, because they would not want to interrupt more important radio traffic. For instance, someone might not want to update road condition information when operators are using the radio to communicate about a crash. Because the App uses data communications that do not impede voice traffic, those who use the App send in more road condition reports and variable speed limit change requests. While this has not resulted in a major change to maintenance operations, it suggests improvements in the way information is shared with the public.

Chapter 3 – System Development and Implementation

The App was planned and designed with input from the maintenance employees. The WYDOT ITS Department's Project Manager met with maintenance personnel to discuss the features they would like the App to have. After feedback was compiled, a set of mockup diagrams and functional requirements was created. These documents were shared with additional maintenance employees, leading to further refinements of the system design. Based on the above, a Concept of Operations document was prepared, which also included the system requirements. Appendix B contains the complete Concept of Operations.

WYDOT ultimately chose to purchase off-the-shelf Samsung® Galaxy Tab4™ tablets with 10.1-inch screens for this project. The Samsung product satisfied the need for an Android™ operating system, communication ports, and Bluetooth connectivity. The Samsung product was significantly less expensive than the other alternatives evaluated for this project.

The Samsung tablets have shown to be reliable and durable. Each tablet has a case that enforces durability, and maintenance workers have reported no problems associated with leaving the tablets in their vehicles.

3.1 Application Development

WYDOT utilized a sole-source contract for this project with *CompassCom*, WYDOT's competitively-bid automated vehicle location (AVL) vendor, because the AVL system provided the key to communicate over the WyoLink radio network. *CompassCom* subcontracted the software development work to *NeoTreks*, a firm with which they had a previous working relationship. The *NeoTreks* project manager began the project by creating wireframe diagrams in March of 2014, while WYDOT employees began work on a data definition document in April 2014. The data flow to and from the App needed to be succinct in order to work well on the low-speed data channel of the WyoLink radio system. Over the course of the following several months and as lessons were learned, refinements were made to the App's interface and to the data definition.

The system was deployed in December 2014 and several enhancements were made after that based on several feedback cycles. These enhancements included the following:

1. Improvements to the speed of positional information by using a SQL Lite local database
2. A versioning method was created that provides the property number, Android operating system version, and App version information for better tracking of the systems
3. A new "Route Info" page was built that allows supervisors to monitor the condition reports from multiple crews
4. A three-phase dimming button was implemented that is conveniently located on the status bar to allow for rapid screen brightness changes

5. Larger buttons for easier control of system settings and reports were standardized throughout the system
6. The ability to report VSLs by selection of either a section or individual sign was added
7. Damage repair reports were added for the convenience of maintenance employees
8. A link to the human resources database feed was made so that each employee only saw the maintenance sections associated with their Department (crew)
9. A “No Unnecessary Travel” button was added to the reporting page
10. Numerous modifications were made to the settings tab allowing for more user preferences
11. Event Log items were modified such that they could be sent as a message
12. The ability to see the information on signs in both directions was added at the request of maintenance employees. Originally, the users could only see information on a DMS and VSL in their direction of travel.
13. Many plow operators found additional free apps that are well suited to their tasks. Apps like a hazardous material placard identification system were added to the tablet for the convenience of the maintenance employees.

3.2 Testing

NeoTreks developed beta versions of the App that were tested by WYDOT staff in the office and in the field. First, functionality was tested in the office to ensure that the App worked as designed with a Wi-Fi connection. Once the functionality was confirmed, the App was tested in the field to ensure that it functioned properly over the WyoLink system. WYDOT’s Telecom Department was an active participant in the testing activities.

Upon completion of the beta testing, a production version was created and shared with the maintenance employees. This process was iterated until a working system was deployed in the maintenance vehicles.

3.3 Other Supportive System Developments

Parallel to App development, WYDOT worked to coordinate backend system development including:

- WTIDB – The data broker was created to direct data into and out of the database.
- WTI – WYDOT also ensured reports coming from the App were not in conflict with reports entered into the WTI by TMC operators. To address this, WYDOT developed a special software to integrate the systems appropriately. Real-time updates to the WTI could be made from the App, even if a TMC operator was actively updating the WTI with a report called in over the radio. Reports made from the App are shown in the WTI with an “A,” while reports called in over the radio are shown with an “M” (for maintenance). This integration has helped to ensure that new information is not inadvertently overwritten with information from an old report.
- TRAC – TRAC was modified to allow reports from the road condition reporting app. Entries into TRAC include the name of the operator and his/her department number, a time stamp, the type of report, all information reported and, if warranted, affected roadside devices that the TMC operator should update.

3.4 Staff Training

Several sessions were held with the TMC Lead Operators to explain and demonstrate the App. This was done early in the launch and repeated when major changes were made to the system.

Training sessions were also held with the maintenance employees. These sessions were usually attended by Telecom employees who were instrumental in the deployment of Wi-Fi hotspots and in the installation of tablets in maintenance vehicles. An introductory session was held with all employees. A follow-up hands-on training was held at the initial launch and repeated when major updates were made. A user manual with screenshots and annotations was created that fully documents the operation of the tablet. The user manual will be available directly on the tablets.

3.5 Vehicle Installation

Tablets were installed in vehicles by WYDOT's Telecom Department staff. Figure 3-1 shows a tablet installation in a WYDOT plow truck. Several configurations were tested and changed during the initial deployment based on driver feedback. The tablets are installed on adjustable stands and can easily be taken out of the vehicle.



Source: WYDOT

Figure 3-1. Tablet Computer Installed in a WYDOT Plow Truck

3.6 Implementation/Deployment

WYDOT has five maintenance districts. For this project, 20 maintenance vehicles located in District 1 and District 3 were outfitted with tablets and the App. The departments that used the tablets were responsible for maintenance of I-80, and a small portion of I-25. Interstate 80 has the vast majority of variable speed limit systems in the State.

NeoTreks developed the App using Android Studio™, an application from Google™. App distribution was managed using the online tool *Hockeyapp*. The map portion of the App was built using ArcGIS™ SDK, an application library from ESRI™ used for map content, including the base map, roads, plow locations, etc. In addition, a WYDOT GIS developer worked to develop services to communicate geo-based information to the App.

There are two ways to update the tablets for new versions of software. A versioning protocol was built into the system that allows administrators to send a global message that is automatically checked each time a user logs into the tablet. If the tablet is not using the version of software recommended by the administrators, a message is sent to the TMC via the TRAC system and the tablet user is offered an opportunity to update the system. If the user chooses not to use the automated method or if there is a problem with the automated update, a manual update method is available. Each tablet is configured with the credentials to a shared Dropbox account. Users are trained to download the App and to do the manual update.

Chapter 4 – System Evaluation Approach

During the project planning phase, a detailed project evaluation plan was prepared. The complete Evaluation Plan is contained in Appendix C. The information below summarizes the evaluation approach.

The system was developed, tested, and operated by January 2015. The evaluation period was January through May 2015. Although the 2014-2015 winter was comparatively mild in Wyoming, there were several significant storm events which enabled collection and analysis of data to complete a meaningful evaluation.

The evaluation plan defined the following four hypotheses to be tested:

1. The application will improve efficiency of condition reporting by maintenance employees and TMC operators
2. The application will improve traffic management capabilities during weather events
3. The application will improve the timeliness of condition reporting updates to the public
4. The application will improve situational awareness of maintenance employees

Table 4-1 summarizes the project evaluation hypotheses, measures of effectiveness (MOEs), and required data elements. The MOEs and data elements represent an evaluation approach that combined both quantitative and qualitative analyses. Additionally, the evaluation approach used the “with-without” methodology, which compared activities using the new road condition reporting application (on the tablets in maintenance vehicles) with the traditional, or standard, practice of using the radio to communicate road conditions. This allowed for comparison during the same weather conditions on similar stretches of roadway.

The quantitative analysis primarily focused on comparing the quantities and/or time spent by TMC operators to receive, log, and process road conditions and suggested traffic management actions for circumstances using the new technology versus those using the standard practices. This yielded some very interesting results which are described in the next Chapter.

The qualitative analysis gathered data through two separate surveys – one completed by TMC operators, and the other completed by maintenance employees. The questions focused on capturing their perceptions, ease of use, and overall impressions of using the new technology. It also asked for their views on the benefits and shortcomings of the new technology.

The next Chapter describes the results of implementing the evaluation approach using the data collected during the 2014-2015 Wyoming winter season.

Table 4-1. Project Evaluation Hypotheses, MOEs, and Data Elements

Hypothesis	MOE	Data Element
Hypothesis 1: The application will improve efficiency of condition reporting by maintenance employees and TMC operators	<ul style="list-style-type: none"> Reduction in the time spent by TMC operators on radio with maintenance field personnel for road condition reporting. Reduction in the time spent by TMC operators to document conditions into logs and traveler information databases. Reduction in time needed by maintenance employees to send road reports. Increase in the number of reports and field codes reported by drivers using the App compared to those not using the App. 	<ul style="list-style-type: none"> TMC and Radio Logs Survey of TMC Operators TMC and Radio Logs Survey of TMC Operators Interviews with Maintenance employees Interviews with Maintenance employees
Hypothesis 2: The application will improve traffic management capabilities during weather events.	<ul style="list-style-type: none"> Increase in the number of accepted maintenance field personnel updates for VSL and DMS Perceived improvement in quality of reportable performance measures. Reduction in time needed by TMC operators to update DMS, VSL and other devices to match road conditions. 	<ul style="list-style-type: none"> TMC and Radio Logs Survey of TMC Operators Interviews with Snow Performance Measures Data Users
Hypothesis 3: The application will improve the timeliness of condition reporting updates to the public.	<ul style="list-style-type: none"> Increase in update frequency of road condition reporting during storm events on App-enabled segments versus those without the App. Increase in timeliness of road condition reporting during storm events on App-enabled segments versus those without the App. 	<ul style="list-style-type: none"> TMC and Radio Logs
Hypothesis 4: The application will improve situational awareness of maintenance employees.	<ul style="list-style-type: none"> Number of maintenance employees who feel more informed about weather conditions when on the roadways. Number of maintenance employees who feel the maintenance App is useful to their operations. 	<ul style="list-style-type: none"> Maintenance application Vehicle Interface Analytics reflecting usage of features by employees. Interviews with Maintenance employees

Source: Battelle/McFarland Management

Chapter 5 – System Evaluation Results

5.1 Background

Wyoming DOT successfully manages their highway road network and traveler information system through a centralized transportation management center (TMC) working closely with their maintenance forces. Field maintenance employees provide both road weather conditions by designated roadway segments and recommendations for traffic management measures (dynamic message signage, variable speed limits, and highway advisory radio messages) on a frequent basis to the TMC operators. The TMC operators then translate the information into important activities (updating traveler information system and taking appropriate traffic management actions). The field data is provided to TMC via radio or cell phone communication. Currently, these standard practices are all executed manually using several systems.

The primary purpose of this WRTM project was to communicate the field data from maintenance vehicles to the TMC using tablet computers in order to improve the efficiency of maintenance and operations activities. A secondary purpose was to automate as many of the processes as possible to support improved operator and TMC efficiencies. Chapter 2 described the technology and system that were implemented to achieve these goals.

In order to achieve these desired efficiency improvements, standard practices of the maintenance staff and TMC operators had to be modified by implementing the following changes:

- Tablet computers with special software were used instead of audible transmissions to communicate road weather conditions and traffic management recommendations
- Manual TMC processes to log field data and update the traveler information system were replaced with automated computer systems
- The new TRAC system which automatically logged the incoming field data from the tablet computers was used by the TMC operators to monitor conditions and take traffic management actions

The traffic management actions utilizing the ATMS system such as changing DMS or VSL remained a manual process. WYDOT is considering automating some or all of these processes in the future.

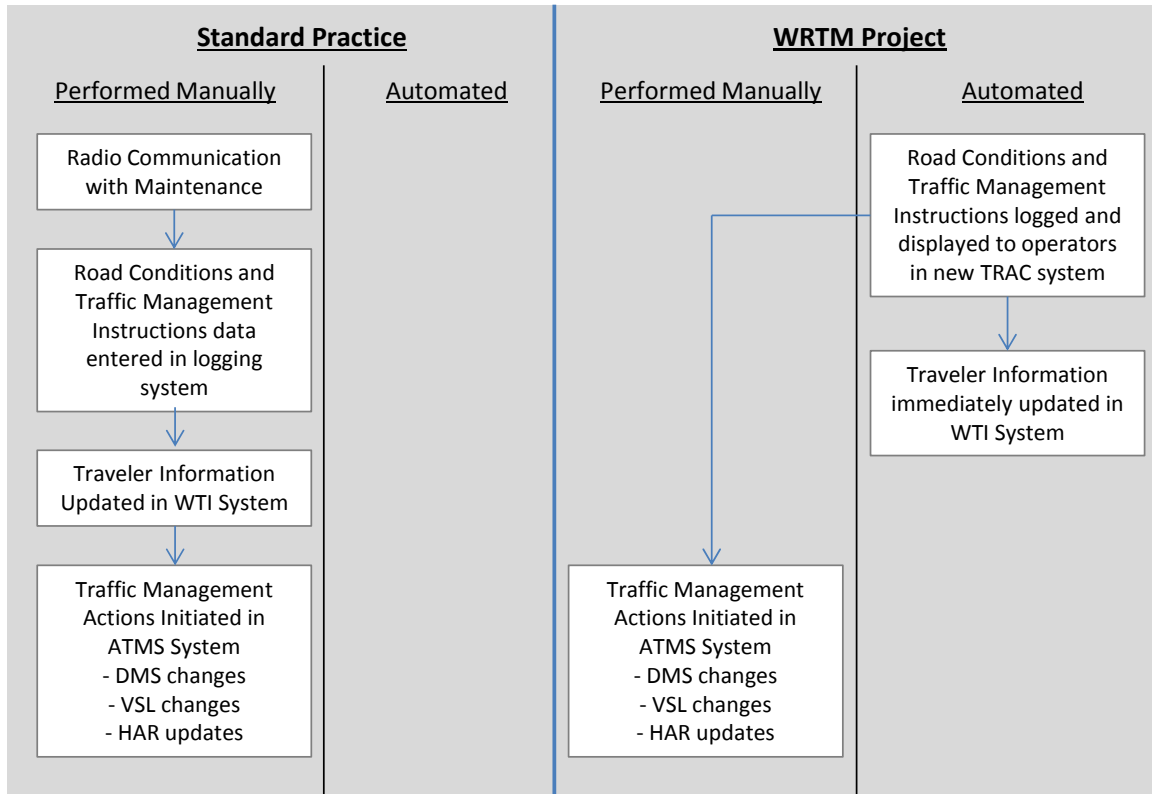
Figure 5-1 summarizes the “standard” and “WRTM Project” practices and illustrates which processes are completed manually or automatically for each case. The figure shows the following processes that are completed automatically or that are eliminated by the WRTM Project:

- Audible radio communication is essentially eliminated for most transmissions. It is important to note that the radio will always remain in the vehicles and available for maintenance forces to speak directly with TMC operators during high priority situations.
- Road condition and traffic management instructions are transmitted seamlessly using the tablet computer in the vehicle to a computer database display in the TMC using the TRAC system. The display informs the operator regarding road conditions by

designated segments. The display also provides the operator details regarding recommended changes to the VSL and DMS by field maintenance employees.

- The traveler information system updates are executed automatically based on field input, eliminating the need for operators to make manual updates.

The evaluation results that follow quantify the efficiency gains through these new processes in terms of time savings, number of reports, and perceived accuracy/timeliness improvements.



Source: WYDOT and Battelle

Figure 5-1. Comparison of Manual (Standard) and Automated (WRTM App) Processes for Road Condition Reporting

5.2 Data Analysis

The results presented in this section include quantitative analysis of data collected and analysis of qualitative responses to surveys. The data collected focused primarily on numbers of road weather condition reports and traffic management recommendations, and time spent by TMC operators executing their duties with and without the App and supportive systems. The two surveys focused on the WYDOT staff (Maintenance and TMC Operators) perceptions of value, benefits, and challenges associated with using the new technology.

This section is organized according to the hypotheses in the Evaluation Plan, which include measuring the efficiency and improvements in road weather condition reporting, traffic management actions, updating traveler information systems, and maintenance staff situational awareness.

5.3 Road Weather Condition Reporting Efficiency (Hypothesis 1)

Evaluation results indicate a significant efficiency improvement in reporting road conditions, logging the data, and updating the traveler information systems using the new App. Summary results are as follows:

1. On average, the number of road reports submitted using the App doubled compared with the number of reports using the standard method.
2. On average the number of VSL change requests received in the TMC using the App was 3 times the number of reports using the standard method.
3. The App allows for timelier submission of road reports, with 91 percent of maintenance staff reported having to wait to use the radio to make their road reports.
4. All maintenance staff survey respondents (11 plow drivers and supervisors) answered “yes” to the question: Do you feel this new technology is useful in your operations?”
5. A significant amount of time is saved when the App is used to automatically submit road reports to the TMC and not having to log the reports or update the traveler information systems.
6. 89 percent of TMC operator respondents said that the agency is better off with the App.
7. 82 percent of maintenance staff survey respondents indicated that the App was either very easy or easy to use.

The detailed evaluation analysis for Hypothesis 1 is presented below.

5.3.1 Road Weather Condition Reporting

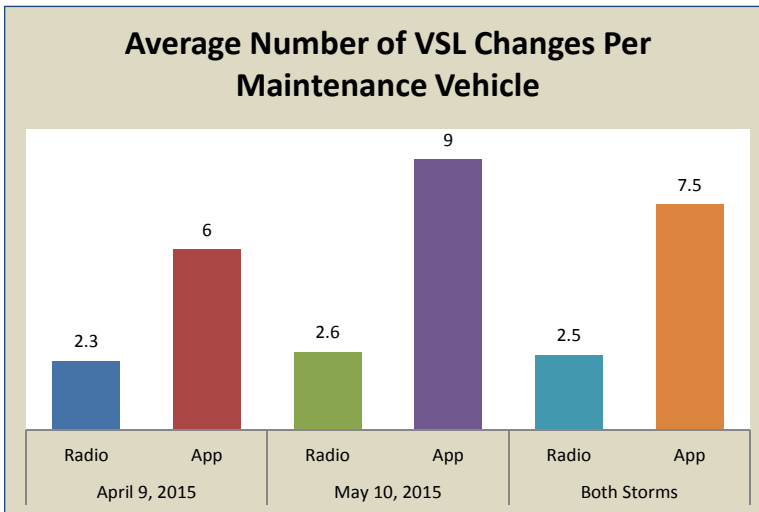
An assessment determined that using the App yielded more road condition reports and VSL change requests compared with the number of reports submitted by the standard practice (radio). Data was collected during two storm periods (April 9th and May 10th) along I-80 between Laramie and Cheyenne. Pertinent information regarding the storm time/duration and the number of trucks reporting the conditions is shown in Table 5-1 below.

Table 5-1. Road Weather Condition Reporting During Storms

Storm Days	Storm Time/Duration	Trucks using App	Trucks using Radio
April 9, 2015	2am-12pm (10 hours)	2	6
May 10, 2015	12am-9:30pm (9 ½ hours)	2	4

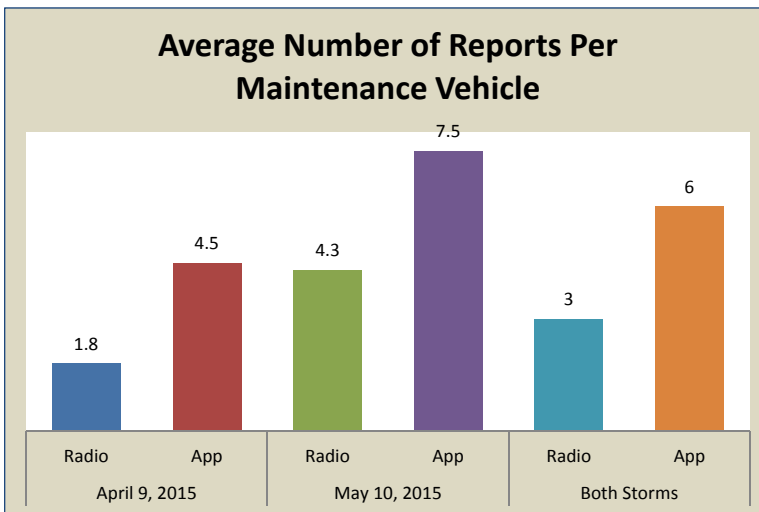
Source: WYDOT

The number of road condition reports and VSL change requests were logged during both storms using the App and using the radio. Averages for each case were calculated. When using the App and considering the case of both storms combined, twice as many road condition reports were submitted and three times as many VSL change requests were submitted on average. Figure 5-2 and Figure 5-3 show the average numbers for the individual storm days and the averages when the two storm days are combined. Although the analyses were conducted only for two storm events, the surveys support the findings, where approximately 64 percent of respondents said they are able to send more reports using the App as compared to using the radio. This is a strong indication that using the App will likely generate a higher frequency of road condition reports and VSL change requests than using the radio. This should translate into more timely and accurate information being provided to the traveling public.



Source: Battelle/McFarland Management, data from WYDOT

Figure 5-2. Average Number of VSL Changes Per Maintenance Vehicle for Examined Storm Days



Source: Battelle/McFarland Management, data from WYDOT

Figure 5-3. Average Number of Reports Per Maintenance Vehicle for Examined Storm Days

U.S. Department of Transportation, Office of the Assistant Secretary for Research and Technology
Intelligent Transportation Systems Joint Program Office

The same proportion (64 percent) of those who responded to the survey also reported that it takes them less time to send a road condition report using the App compared with using the standard practice (radio). Ninety-one percent reported that they were able to send road condition reports using the App without waiting, whereas the radio traffic would have interfered with their reporting and made them wait for “gaps” in order to report the conditions. During interviews with WYDOT maintenance staff they indicated the radio wait time on average ranged from 1 to 15 minutes depending on the level of radio use at that time.

The results from the maintenance staff surveys and interviews were very positive toward the new approach to reporting road conditions. Probably the most telling result was that 100 percent of the respondents (11 plow drivers and supervisors) answered “yes” to the question: “Do you feel this new technology is useful in your operations?” Other notable results and comments are listed below.

- 82 percent of the survey respondents indicated that the App was either very easy or easy to use
- When interviewed, maintenance staff indicated the primary benefits as:
 - GPS location – knowing exactly where the driver is during weather events
 - Reduction in radio usage – can wait up to 10-15 minutes for radio time.
 - Knowing what the reported conditions are in nearby areas
 - Recommending VSL changes – “100 percent easier than using the radio”
 - Weather radar and RWIS data access
 - Mostly used for Code 10-13 reports (road and atmospheric), but other uses are very handy such as reporting incidents, equipment damage, etc.
 - Accuracy of information provided to TMC
- App is less distracting than using the radio
- More likely to use App to update Code 10-13 reports – easier to provide updates
- Foremen (in pickups) can be out in the field more using the tablet for information rather than having to get the same information from their desk computers.

5.3.2 Road Weather Condition Logging and Traveler Information System Updates

Time studies were conducted to determine if TMC operators spent less time logging road conditions and updating the traveler information systems when receiving information from the tablet computers via the App versus the standard method. It is important to remember that information received via the App is provided to TMC operators on the TRAC screens and the road reports automatically update the traveler information system. If the information is received by the standard method then the TMC operators must log the information into one system and manually update the traveler information database in another system (see Figure 5-1). Therefore, it was anticipated that time would be saved by TMC operators to log information and update traveler information systems.

During a normal winter day, 33 radio calls were taken by three TMC operators and the time was recorded for them to log information and update the traveler information database. On average, the time to perform both these activities ranged from 38 seconds to 43 seconds per radio call, depending on the experience level of the operator. A similar study was conducted during a major winter storm event and the time to perform the same activities increased to 85 seconds on average per radio call over 19 calls due to more activity in the TMC during weather events.

These values are considered direct time savings. When information is sent via the App, there is no need to log the calls or update the travel information systems. Although this is a limited study, WYDOT believes that this is a true representation of the actual conditions on a regular basis in the TMC.

Extrapolating the time savings per road condition report yielded significant monthly/yearly time savings. Based on WYDOT road reports including storm days and non-storm days from January 2014 to December 2014, WYDOT estimates using the App results in more than one person-year time saved. Table 5-2 below includes the data used and calculation made with notes to describe the analysis. The time savings gained from automated reporting can be used to focus on high-priority activities and to improve timeliness of activities and actions taken in the TMC. This analysis assumes that all WYDOT plow trucks are outfitted with tablets operating with the new App. This should be considered a conservative estimate because it only includes time saved due to logging road conditions and updating traveler information systems. It does not account for other TMC tasks that may also result in time savings including traffic management and road closure actions. Looking forward, WYDOT anticipates an adoption rate of 75 percent.

Table 5-2. Calculation of Projected Hours Saved in TMC Operations Using the App to Collect and Transmit Road Condition Reports

Month	Number of WTI Updates (storm)	Number of WTI Updates (non-storm)	Total Savings (hours)
January 2014	11,841	59	280.2
February 2014	12,318	101	291.9
March 2014	11,624	518	279.9
April 2014	7,615	1,701	197.8
May 2014	4,159	3,593	136.1
June 2014	1,986	5,259	102.4
July 2014	1,566	4,203	81.3
August 2014	1,755	4,705	91.1
September 2014	2,012	4,163	91.4
October 2014	2,795	3,444	102.3
November 2014	9,264	1,308	232.5
December 2014	10,198	610	247.2
Totals	77,133	29,664	2,134.3

Notes:

- 38 seconds on average savings (experienced user) was applied to non-storm updates
- 85 seconds on average savings was applied to storm updates
- Total Savings calculation: $((\text{number of WTI storm updates} * 85) + (\text{number of WTI non-storm updates} * 38)) / 3600$

Source: Battelle/McFarland Management, data from WYDOT

Survey of TMC Operators supports the quantitative findings:

- 87 percent of respondents said that the new application allowed them to spend less time logging radio calls
- 89 percent of respondents said that the agency is “better off” with the App

Other notable results and comments from TMC Operator personal interviews are listed below.

- Significant time saved logging road condition reports and updating traveler information through new data automation (TRAC and WTI).
- Primary benefits noted:
 - Significant reduction in radio traffic – allowing radio operations/reporting to focus on urgent and safety related activities
 - Frees up your hands (not using radio) to handle high priority functions
 - Road condition updates are more frequent and therefore more accurate
 - Reporting the exact location of incidents
- TRAC allows supervisors to easily “monitor” conditions of incoming information across state
 - Also provides “task list” of needed actions
- Currently, TRAC feed is statewide. Need to divide TRAC feed by District to help TMC operators better focus their efforts on high-priority actions

5.4 Traffic Management Improvements (Hypothesis 2)

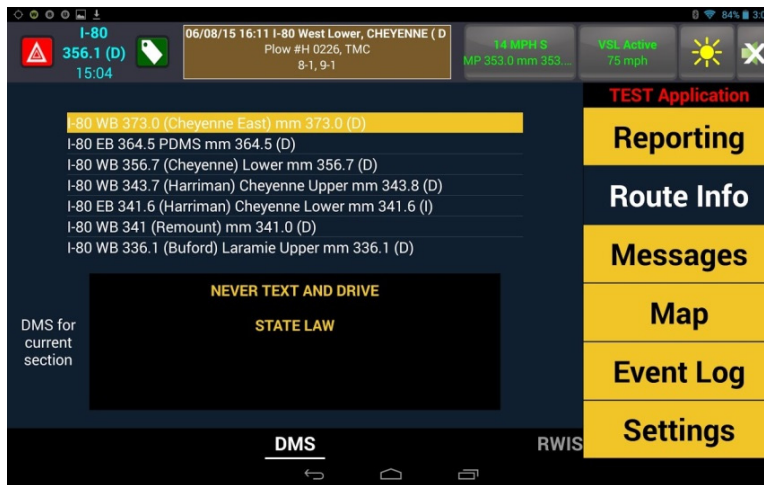
For this hypothesis, traffic management focuses on message and/or information updates to VSL and DMS signs. The evaluation resulted in the following:

1. The App is easier to use than the radio to provide the TMC with recommended VSL and DMS changes
2. More VSL and DMS message changes were requested using the App
3. The information associated with the VSL or DMS change is more accurate using the App which allows the operators to act more quickly and with more confidence
4. 78 percent of the operators surveyed indicated that it was easier to know which DMS to update when the request came via the App
5. The time taken by operators to update VSL or DMS messages was the same regardless of the request transmission type; however, system enhancements have been identified to save time in the future

The detailed evaluation analysis for Hypothesis 2 is presented below.

5.4.1 Traffic Management Recommendations

WYDOT maintenance staff makes recommendations to the TMC operators to change Variable Speed Limit signs (either decrease speeds because of hazardous driving conditions or increase/resume speeds when the hazard is reduced or gone) and display messages on the DMS regarding conditions or incidents ahead. Most DMS changes are made by the TMC Operators as a direct result of a road condition report from maintenance staff. Currently these recommendations are made via audible radio communication. The App displays the DMS messages in a given area for the maintenance staff to view. This information assists maintenance staff in performing their duties. Figure 5-4 shows a tablet screen shot of how several DMS messages can be displayed in the maintenance area currently being addressed by a particular plow truck. Maintenance staff can also request a change to a message sign via the radio to the TMC.



Source: WYDOT

Figure 5-4. Tablet Screen Used to Recommend a Change to a DMS Sign

As previously discussed, analyses indicated that using the App resulted in 3 times more VSL change requests being recommended compared with using the standard method. Interviews with the maintenance staff indicated this might be the case because of the following reasons:

- The App is easier to use and more accurate to describe a VSL change request
- Radio traffic is heavy during active weather events and transmission opportunity is not always available
- Maintenance staff can be shy about using the radio
- Noise in the plow trucks makes it difficult to hear and transmit information over the radio

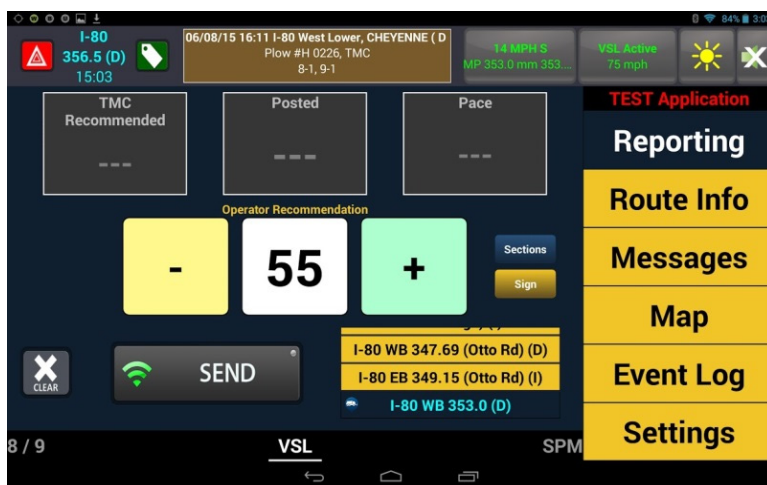
For similar reasons, more frequent DMS recommendations can be made using the App. Since most of the DMS changes made by the TMC are executed based on the road condition reports, and the analysis showed that the App results in twice as many road condition reports (when compared to the standard method), it can be concluded that more DMS changes are likely to be made when information is received in the TMC using the App.

Another measure of effectiveness was how the App might help in logging the data to support snow performance measurement. Of the 11 maintenance staff who responded to the survey, 7 said they are not required to collect this type of data. All of the other 4 respondents indicated that the App improved their ability to report snow performance measures.

Interviews with maintenance staff and TMC operators indicated that using the App (instead of the radio) to transmit traffic management recommendations were easier and provided more accurate information for Operators to act upon at the TMC. In support of the interviews, the TMC operator surveys indicated that 78 percent of respondents said it was easier to know which DMS to update when the input came via the App.

5.4.2 Traffic Management Actions

TMC operators use the information transmitted by the field maintenance staff to execute traffic management actions such as changing VSL signs or displaying new messages on DMS. TMC operators perform other actions such as road closures. However, those activities were not the focus of this evaluation. Figure 5-5 shows the screen used to request a VSL sign change.



Source: WYDOT

Figure 5-5. Tablet Screen Used to Request a Change to a VSL Sign

The maintenance staff recommendations are displayed on the TRAC screen for TMC Operators to review and decide what actions to take. As described earlier, the Operator actions to change a VSL or DMS sign is manual regardless of what method is used to transmit the recommendation (radio or App).

Additional studies found that the time it took a TMC operator to update a VSL sign or DMS was the same whether they received the information via the radio or the App. There was no reduction in time to update the signs using the App. However, the interviews with maintenance and TMC operator staff indicated the following important factors regarding the benefits and potential improvements:

- Information received by the TMC operators using the App is more accurate (i.e., location, instruction, etc.) than using the radio thus allowing the operators to act more quickly and with more confidence, as well as make fewer errors
- Operators also believe they are receiving more VSL change requests using the App

- The TRAC system requires the following enhancements:
 - Refresh rate is too long which can delay the recommendation requests by up to 30 seconds
 - Need an audible tone or something else to alert the operators of important TRAC messages so actions on high priority items such as a VSL change requests can be more timely

Based on this input, it is believed that time savings to update VSL and DMS are possible with future updates to process and software.

5.5 Timeliness of Updates to the Public (Hypothesis 3)

The timeliness of traveler information updates to the public involves two important elements:

1. How quickly the information can be collected by maintenance and transmitted to the TMC. A related aspect of timeliness is the frequency of road condition reports – the implication is that if more reports are collected and transmitted in a given time period, then the timeliness of accurate information provided to the public improves.
2. The operator’s ability to make the appropriate traveler information updates based on the data received from the field.

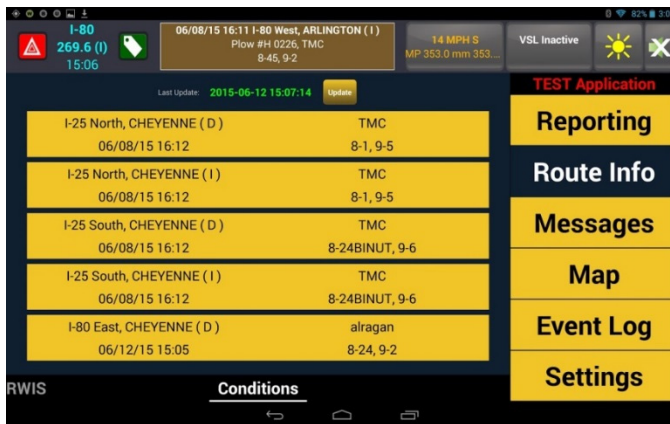
For the first element, we have already established (in the analysis of Hypothesis 1 above) that in a given time period (during the same weather event and in the same maintenance section) twice as many road condition reports were submitted by field maintenance personnel using the App compared to those submitted by the standard method. This is a significant increase in frequency of road condition reports which implies an improvement in timeliness. The “quickness” of submitted reports by maintenance staff could not be quantitatively measured; however, 64 percent of respondents to the maintenance survey did say that it took them less time to submit a road report using the App. The same 64 percent also said they were able to send more reports and field codes using the App when compared to using the standard method.

On the second point, the TMC operator’s ability to update the traveler information system when information is received using the App has been completely automated. The TMC Operator no longer needs to take any action to update the traveler information system. The enhanced system directly improves the timeliness of traveler information communicated to the public. Previously described analysis suggests an improvement of 38 seconds and 85 seconds per update action for typical winter weather and severe storm events, respectively. Considering the large number of updates performed in a typical winter month, this translates to roughly 280 hours in a single month of improved timeliness of traveler information updates.

5.6 Situational Awareness of Maintenance Staff (Hypothesis 4)

Another key aspect of the App includes providing plow drivers with important information that improves their situational awareness and assists them with their duties. This information includes:

- Road reports from nearby areas—shown on Figure 5-6 tablet screen shot
- RWIS data
- Weather radar
- Specific GPS and milepost location of the plow truck
- Messages from the TMC



Source: WYDOT

Figure 5-6. Tablet Displaying Road Reports from Nearby Areas

Responses from surveys and interviews of maintenance staff indicate a strong support for the availability of such information. The two most noted were road reports from nearby areas and specific milepost location of the plow truck they are driving. Related survey responses included:

- 73 percent said they feel more informed about road conditions within their area of operation – this helped them to know what road condition was already reported so they only needed to submit a report if those conditions changed
- 100 percent said they found the milepost location useful – this helped them to know their exact location especially during weather events and to report the precise location of an incident

Chapter 6 – Conclusions, Lessons Learned, and Next Steps

6.1 Conclusions

Development, implementation, and evaluation of the Wyoming DOT Road Condition Reporting App resulted in the following conclusions:

1. Strong support for the App and corresponding system was expressed by both maintenance staff and TMC operators with 100 percent and 89 percent, respectively, stating that the DOT is better off with the new system.
2. In addition to the App, traffic management was improved through the development and implementation of supporting data management systems, such as TRAC and traveler information update automation software.
3. Significant TMC operator time savings were calculated from the automation of several key tasks – data logging and traveler information system updates. Based on road reports including storm days and non-storm days from January 2014 to December 2014, WYDOT estimates that using the App can result in more than one person-year of time savings.
4. Efficiency of data collection, transmission, and management were realized, allowing for a higher frequency of road condition reporting and VSL change requests.
5. Accuracy of the traveler information was improved due to higher-frequency reporting of the conditions from the field and resulting higher DMS/VSL update rates.
6. Accuracy of information transmitted to the TMC from the field was substantially improved, specifically road condition reports, VSL change requests, and other reporting such as location of incidents.
7. Future system enhancements were identified to further refine the App and related systems to improve the application of the new technology in the next winter season.

6.2 Lessons Learned

The initial implementation of the App was technically complex and required intense management attention. As expected, the project experienced some challenges. Following are some of the key challenges the WYDOT team addressed:

1. First and foremost, the communication system using the data channel of the WyoLink radio network proved to be more difficult than anticipated, and more effort should have been invested earlier in the project to ensure the communication system needs and requirements were well understood and developed. The project was delayed by a few months because of this problem.
2. Positional information is very important for maintenance employees (particularly in a blinding snowstorm) and the first attempt to provide this information using a GIS application program

- interface was too slow. This problem was corrected by deploying a local SQL Lite database that contained all positional data.
3. More effort should have been made to inform the TMC operators about the new system. Some operators did not fully understand the objectives and details of this project. Thus, early outreach and project education would have helped to ensure a smoother implementation.
 4. After one update to the system, an intermittent communication bug with the WyoLink radio system was introduced into the parser. This was not realized prior to release of the version, and maintenance employees suffered with this problem without reporting it to TMC management for almost 1.5 months. Once the problem was relayed, it took five days to root out and fix the problem.

Much was learned during this initial implementation, and WYDOT plans to incorporate system enhancements to further refine and expand the system.

6.3 Next Steps – Future Expansion

WYDOT intends to expand the installation of the road condition reporting app in as many as 150 vehicles for the next winter season. The state received federal funds that will be used to purchase additional hardware and complete additional system developments to further integrate the App into existing systems. Tablets will be given to all maintenance areas at a future time. Selection decisions will be based on targeting high traffic areas and departments with the strongest interest. WYDOT districts will continue to provide input and assist with future system development.

In addition, WYDOT intends to take advantage of the functionality of the tablet computers by developing web apps to create electronic versions of paper forms currently used in maintenance operations such as those used for vehicle inspection and repair requests. The App is also being treated as a proof of concept, and the basic functionality could also be expanded to accommodate other department activities such as construction management.

Chapter 7 – Recommendations

Implementation of WRTM strategies over the past few years have been fairly successful, and this WYDOT project on mobile data collection and processing is no exception. FHWA intends to continue this success with future WRTM strategy implementations. The following recommendations will assist the FHWA RWMP in its efforts to advance the WRTM Program and expand partnerships with state DOTs.

7.1 Recommendation #1 – Continue Outreach and Education of Recent WRTM Strategy Implementation Successes to Other State DOT’s

As a program, WRTM continues to be recognized around the U.S. as a set of strategies that can improve traffic management operations during weather events. The WYDOT implementation serves as a positive example that provides evidence of the potential benefits of the WRTM program. However, much can still be accomplished to educate and encourage the state DOTs to conduct research and implement strategies that meet their specific needs. FHWA should continue to inform with state DOTs and spread the news of the WRTM successes, lesson learned, and future possibilities. This can be accomplished through newsletters and project flyers, participation at related conferences, and conducting the biennial WRTM Workshop.

7.2 Recommendation #2 – Continue to Build on WYDOT’s Successful WRTM Implementation

WYDOT’s WRTM project documented herein was a great success for Wyoming traffic management operations as well as for the FHWA. WYDOT is planning to expand on this implementation and continue to develop new applications to leverage the recent efforts. This includes increasing the number of tablets in plow trucks for the upcoming winter and developing a vehicle inspection application on the tablets that maintenance staff can use to log and transmit information. Wyoming has also been an innovator for addressing road weather challenges, and contributes to WRTM national best practices. FHWA should continue to monitor the progress of Wyoming’s WRTM applications and work with WYDOT on their future endeavors as a strong partner in the WRTM program.

7.3 Recommendation #3 – Expand Road Weather Mobile Data Applications to Integrate WRTM and the Connected Vehicle Programs

It has been shown that there are many benefits associated with the integration of connected vehicle and mobile application data into WRTM strategies. Benefits of WRTM mobile data application data strategies can be directly assessed through measured operational performance improvements. FHWA should continue to emphasize the incorporation of mobile data and connected vehicle data for traffic management during weather events. This includes emphasis on both the data processing and, most importantly, developing plans for operators to act upon the data that is received. These operator actions and the thresholds at which the actions occur need to be carefully correlated to the measureable weather operations performance targets. As connected vehicle infrastructure continues to expand, so will the amount of WRTM-related information. This influx of connected vehicle data will result in an increased coverage, more frequently updated and higher-resolution road weather information. Ultimately, a system capable of handling the growing volume of road weather data will be an integral element in providing decision-making support regarding traffic management during various weather conditions.

7.4 Recommendation #4 – Continue Research and Monitoring of Mobile Data Applications and Practices

WRTM mobile data applications and practices take on many different forms in various states depending on the states' specific needs. Additionally, the data generated is used to improve state DOT operations and traveler information dissemination on many different ways. In Wyoming's case and as documented in this report, WYDOT focused on the operational improvement of road condition reporting and the transmission, and the processing and management of the resulting data. Other states may have different needs or objectives. FHWA should continue to monitor and document best practices for WRTM mobile data applications. Additionally, research and future implementations are needed to complete the knowledge base of what is possible in this arena. FHWA could continue to share what is learned with other states to help promote and encourage expansion of WRTM mobile data applications in other parts of the Country.

7.5 Recommendation #5 – Continue to Provide Funding to State DOTs for WRTM Implementations

To date, FHWA has funded or partially funded six WRTM implementation projects in five states—Michigan, Oregon, South Dakota, Utah and Wyoming. Those projects have been successful in advancing the WRTM technologies and applications. Those implementations also demonstrated improvement in traffic management operations during weather events. It is notable that two of the projects have been honored with a Best of ITS award – Utah and Oregon. This was made possible with the FHWA funding to assist the states to implement WRTM strategies that they were already considering to improve their operations. FHWA should consider providing this type of “seed” funding for state DOT projects that are aligned with the current program's objectives. This may include future efforts to integrate WRTM strategies with the Connected Vehicle Program.

Appendix A – List of Abbreviations and Acronyms

AVL	Automated Vehicle Location
CAD	Computer-aided Dispatch
DMS	Dynamic Message Sign
DOT	Department of Transportation
ESRI	Environmental Systems Research Institute
FHWA	Federal Highway Administration
GIS	Geographic Information Systems
HAR	Highway Advisory Radio
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
LDE	Location Data Engine
LMU	Location Messaging Unit
MOE	Measure of Effectiveness
RWIS	Road Weather Information System
RWMP	Road Weather Management Program
SQL	Structured Query Language
TMC	Transportation Management Center
TRAC	Transportation Reports and Action Console
VSL	Variable Speed Limit
WRTM	Weather Responsive Traffic Management
WTI	Wyoming Travel Information
WTIDB	Wyoming Travel Information Data Broker
WYDOT	Wyoming Department of Transportation

Appendix B – WYDOT WRTM APP Concept of Operations

WYDOT Plow Operators App Concept of Operations

Wyoming Department of Transportation
GIS/ITS

April 8, 2014

List of Abbreviations and Commonly Used Words

8 Code	Road condition information
9 Code	Weather condition information
10 Code	Official signal code
TMC	Transportation Management Center
ITS	Intelligent Transportation System
VSL	Variable Speed Limit
RWIS	Road Weather Information System
DMS	Dynamic Message Sign
AVL	Automated Vehicle Location
Road segment	Spans from one city to another
Road section	A portion of a road segment (typically associated with a Maintenance Section)

Executive Summary

The State of Wyoming is seeking to work with one or more contractors to build the WYDOT Condition Reporting App, a touch screen-based road reporting system that will be used by maintenance employees to report near real-time road conditions to the traveling public and to WYDOT's Transportation Management Center (TMC). The system will also receive road weather information from state and outside sources. The app will primarily be used on a mobile operating system, but WYDOT is also interested in having a version that works on a PC so it can be made available to other WYDOT personnel.

The product will allow maintenance employees to share road condition information directly with the public. To do this, the app must be able to communicate with an Oracle database. In addition, the app must be able to send information to operators in WYDOT's TMC to enable them to make adjustments to variable speed limits (VSL), dynamic message signs (DMS) and other devices. Because maintenance employees and TMC operators will both make changes to the database, there could be a conflict. WYDOT intends to work with the contractor to come up with ideas to help address any problems that could arise. The app will also be used to collect information necessary for compliance with the Federal Highway Administration's MAP-21 regulations.

In addition to sending information to the database, the app will receive information from the database to provide maintenance employees with in-vehicle weather forecast from meteorologists, information from road weather information systems (RWIS) and information from roadside devices to help them better prepare for changing weather conditions and communicate current road conditions and safety warnings to the public. They will also receive vehicle location information on a map page and download weather radar images from the National Weather Service.

Because cell service in Wyoming is not available in all locations and because monthly data contracts are expensive, the system will operate over the WyoLink radio system and over Wi-Fi, when available. WyoLink is a statewide digital trunked VHF P-25 compliant public safety communications system. WYDOT uses the system now for radio communication and to transfer data. The app will tie into some of the existing in-vehicle equipment, including CompassCom automatic vehicle location (AVL) and Roadwatch temperature sensors. The AVL reports vehicle position, speed, and direction of travel. Information from AVL is already being captured and delivered to WYDOT databases through WyoLink. The low-speed data path sends data every three miles or three minutes. If radio coverage is unavailable, data is stored and forwarded when it becomes available again.

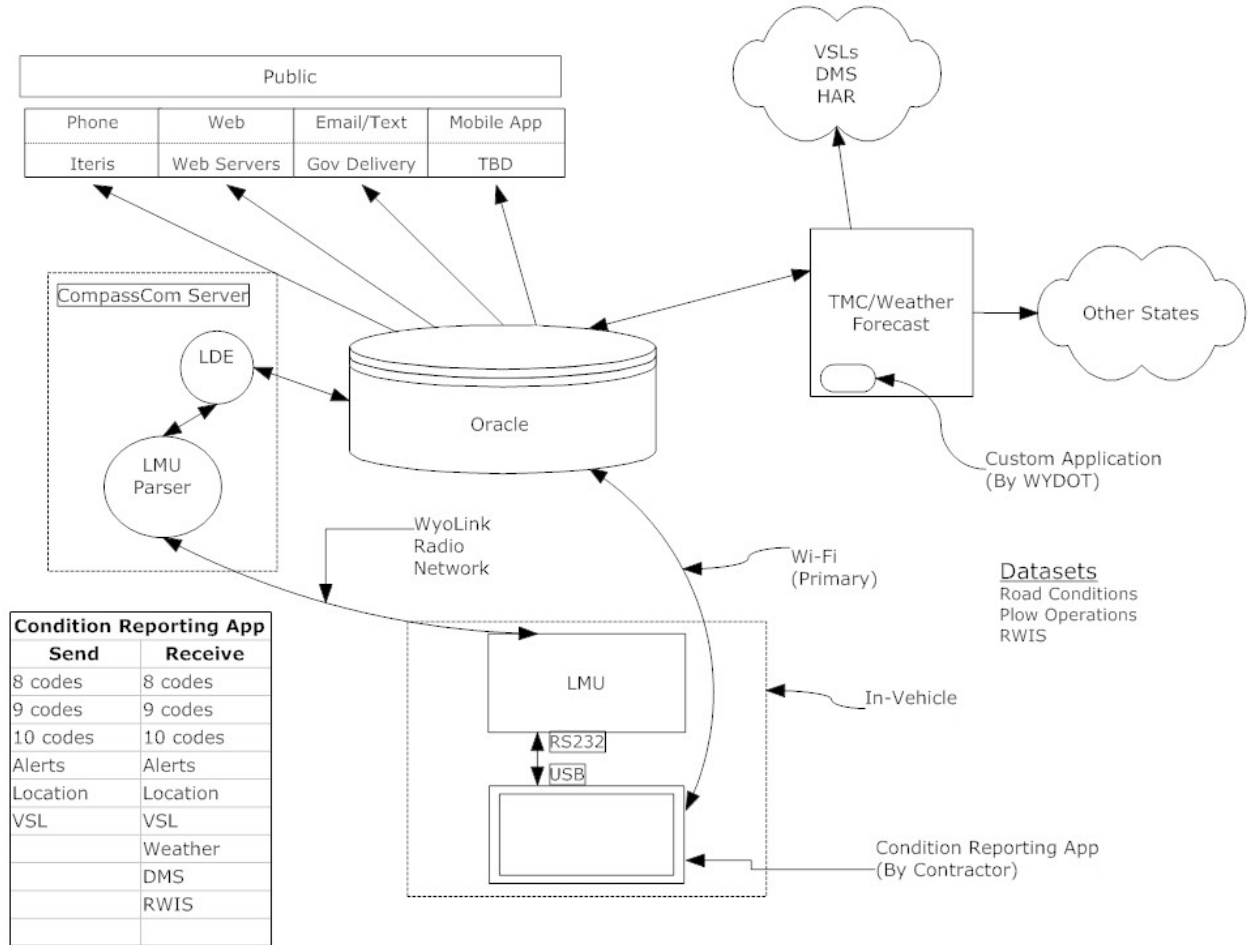
WYDOT relies heavily on maintenance employees to provide information about road conditions, and this app is intended to make it easier and more efficient. Using a cell phone or radio, maintenance employees provide reports based on a standard set of road surface conditions (8 codes), atmospheric conditions (9 codes), and other conditions (10 codes). That information is relayed to the TMC where operators record the conditions, report the conditions to the public, and, if warranted, make adjustments to roadside devices, including variable speed limits, dynamic message signs, highway advisory radios, etc.

The systems in place allow WYDOT to share road conditions with the public and use the information to improve roadway safety through roadside devices, but they could be improved to make reports more timely and accurate. Maintenance Employees report road conditions based on maintenance sections, which have fixed boundaries based on maintenance crew responsibilities. Because the boundary lines have been determined based on manpower requirements, the maintenance sections aren't always the best delineators to use to give an accurate representation of road and atmospheric conditions. A better option would be to capture road and weather conditions by milepost and to make

the more accurate reports available to the TMC operators and to the public. While this isn't something that will be implemented short-term, the app could help make that a long-term possibility.

The app will be used in a pilot project with participants from crews who work in two WYDOT maintenance districts along Interstate 80 and Interstate 25. We anticipate system development to begin in February, with the app available for the 2014-2015 winter season. We intend to be able to make changes to the app during the 2014-2015 winter season, so we can try to fix any problems that arise and evaluate the solution.

Figure B-1 shows how the condition reporting app will interact with existing systems.



Source: WYDOT

Figure B-1. System Data Flow Diagram

PROJECT GOALS

The purpose of this project is to improve WYDOT's road condition reporting process. To accomplish this, the condition reporting app is expected to: improve efficiency for condition reporting, reduce the burden on TMC employees, reduce the lag between the time reports are made and public interfaces are updated, increase the information made available to maintenance employees and improve the way snow performance measures are recorded. These ideas are explained more fully below.

Improving efficiency for condition reporting

Currently, maintenance employees report conditions to TMC operators using the WyoLink radio system. There are two primary reasons why a maintenance employee might have to wait to make a report: Only one person can speak on a particular radio channel at one time. During busy times maintenance employees often must wait until a channel is free before making a report. When there is a shift change, this can mean there are a number of people who must wait to report they are beginning duty and in service. Additionally, when fully staffed, the TMC has one operator working for each of WYDOT's five maintenance districts. While operators in one district can and do step in to help operators working other districts when time allows, generally one person is responsible for recording information from all maintenance employees in the district. Operators must finish recording information from one maintenance employee before being free to record information from another.

Through the app, maintenance employees will be able to take advantage of the store and forward function of the WyoLink system. Instead of having to wait until a channel is free, the maintenance employee can report when it is most convenient and safe for him or her. The report might be held until there is available capacity, but the maintenance employee will be able to continue with other duties.

Reducing the burden on TMC employees

As explained above, when fully staffed there is generally one TMC operator to cover each of the five districts. When the operator takes a radio call, he or she logs in the information and then enters it into the Wyoming Travel Information system, which is used to update the database that provides information for the state's website and phone system. The operator duplicates efforts by recording information in the log and re-entering it into the WTI. Additionally, operators often receive back-to-back radio calls. This means they might enter information from multiple maintenance employees into the log and then go into the WTI and enter the information there. As WYDOT adds more and more ITS devices, including additional dynamic message signs and VSLs, operators are going to be asked to spend more time updating devices, adding additional burdens to their workload.

Through the app, operators will not have to enter information into the log because the information will already be recorded. Since the user will directly update the database, it will also mean less time spent recording conditions in WTI. Cutting back on this data entry will allow the operator more time to spend updating additional devices.

Reducing the lag between the time reports are made and public interfaces updated

When fully staffed there is one TMC operator for each of WYDOT's five districts. The operators are asked to log all radio calls and then make changes to the WTI. During busy times, operators might have to log information from multiple maintenance employees before getting the chance to update the public information systems. When radio traffic is heaviest, weather and road conditions are often at their worst and more people are looking to the website and phone system for updated information.

Through the app, maintenance employees will directly update the database that feeds the website and phone system, which should cut the time between when a report is made and when the information is made available to the public. There could still be a lag time based on limitations of the WyoLink system, but there will be fewer steps in the process.

Increase the information made available to maintenance employees

Information from maintenance employees is vital to travelers in Wyoming who use information from road reports, DMS and VSLs to make travel decisions. While maintenance employees provide information, they are often times cut off from receiving it. This information can help them make decisions regarding treatment methods for roadways. The app will not, however, be a means for treatment recommendations to be provided to maintenance employees working in snow plow.

The condition reporting app will allow maintenance employees to receive the same information being provided to travelers and more. The app has pages to provide weather information from nearby RWIS, messages posted on DMS, and posted speed limits in VSL zones. All of this information is currently made available to the public by WYDOT. Additionally, users will receive weather forecasts from meteorologists contracted to work with WYDOT and weather radar images from the National Weather Service. None of this information is currently available to maintenance employees in the field, though it is publicly available.

Additionally, maintenance employees will see what information is being reported to the public and what posted VSLs are in comparison to posted and recommended speeds. This can serve as a way to alert maintenance employees when an update is needed.

Maintenance employees currently have access to information regarding reported road condition information because they are able to hear reports over the radio as other operators call in to the TMC. With the app, that radio traffic will no longer be available. To remedy that, the app will have features that allow road condition information to be read based on parameters set by the maintenance employee. In addition, they will always be able to see the reported road conditions for his or her current location. This will allow the maintenance employee know if an update is needed.

Improve the way snow performance measures are recorded

The current process to record information for snow performance measures is manual and cumbersome. After a shift, the employee must go back to the shop and record information on a spreadsheet and send it to a meteorologist working out of WYDOT's TMC. The meteorologist then copies the information obtained from the maintenance employee and records it in a separate spreadsheet. Much of the information being reported by the maintenance employee is already being stored in WYDOT databases. Other information, including visibility and snow accumulation, can easily be reported through the app, eliminating the need for the manual process.

PROPOSED SYSTEM

The WYDOT condition reporting app will improve efficiency in WYDOT's road-weather information system by allowing maintenance employees to report road conditions in near real-time to the traveling public and to WYDOT's Transportation Management Center. Maintenance Employees now use the statewide WyoLink radio network to communicate with TMC operators. While this system works, there are limitations based on the number of people who can communicate with the TMC at one time. The app will allow maintenance employees to report conditions when it is most safe and convenient for them and allow the information to be transmitted when system capacity allows. While the app will primarily be used on mobile operating systems, WYDOT is also interested in a version that runs on

PCs. WYDOT would like to limit functionality in the PC version so it can be shared with other WYDOT employees, giving them the benefits of information, but not allowing them to make changes to the database.

In addition to sending reports, maintenance employees will receive information necessary to improve the way variable speed limits are set, to make sure road condition information is accurate and to allow them to change treatments based on current and projected changes in weather. This information will come from readily available web sources and will not include treatment recommendations. WYDOT and the developer will agree on the format of one or more comma separated text fields which will be used to send and receive information to and from the condition reporting app. A text stream provided by WYDOT will be used to populate information displayed on icons.

Section 3 includes a detailed list of functional and system requirements.

1. App Overview

This section provides an overview of the WYDOT Condition Reporting App and its various functions. The app will allow maintenance employees to report road condition information, crash information, obstructions in the roadway and motorists in need of assistance, and to make recommendations for variable speed limits. It will also allow them to receive and send messages and to receive information about variable speed limits, weather, dynamic message signs, and road conditions. This information will be based on maintenance sections, road segments and road sections. Road segments span from city to city. Road segments are divided into road sections. WYDOT will provide the contractor with boundary information.

For road condition information, information sent from the maintenance employees will go directly to the database behind the www.wyoroad.info website and 511 road condition information telephone system. Every time a maintenance employee updates the database, operators in the TMC will be informed of the change. For all other reports, information will be sent to TMC operators. If the operator does not acknowledge receipt of reports within five minutes, a TMC Lead via a popup and the TMC supervisor will be notified via an email. Information sent to maintenance employees will come from various sources and is explained more below.

1.1 Sending Information

Maintenance employees will be able to send reports in real time or after the fact.

To send information in real-time, operators will push a button corresponding to appropriate 8, 9, or 10 codes, a recommended variable speed limit or other report. After making a selection and hitting send, the send button will turn yellow as an indication to the user that the transmission is pending. Once the transmission is complete, and, if applicable, the database has been updated, the send button will return to the default color. There will also be an option for voice control. Using voice control, an employee will activate the app, speak the appropriate 8, 9 or 10 code or variable speed limit and say "send." The send button will turn yellow in confirmation and return to the default color after transmission is complete. If the transmission does not go through after five minutes, the system will alert the user by turning red and with an audio cue to call in the road report.

After the employee sends the report, any 8 and 9 code selections will remain selected and be shown as highlighted. To report the same conditions for a different location or to show conditions haven't changed, maintenance employees can hit the send button and the information will again be sent, but updated with a new location and/or timestamp. The employee could also select additional conditions to report or tap an already selected condition button to deselect it.

When a maintenance employee hits send, only information displayed on the active page will be sent. Or, if in voice reporting mode, only the conditions spoken will be sent. This is intended to keep maintenance employees from resending road condition reports that have not been updated when suggesting a change to a variable speed limit or sending information about a 10 code.

A toggle button will allow the user to switch from real-time reporting to post reporting. In post reporting mode, which will only be available when the vehicle is not moving, the interface will change. For road condition reports and 10 code reporting, maintenance employees will be able to select the type of report they would like to submit from a drop down menu. They will enter location information based on their vehicle location, places they previously GeoTagged, places they previously travelled or by entering route and mile post information. For VSL updates, they will select a speed limit to correspond with a VSL sign.

In most cases the information sent from maintenance vehicles will populate the database, making changes immediately to Wyoming Travel Information and the website and phone system it feeds. TMC operators will be notified of changes immediately so roadside ITS devices can be changed, if necessary, and operators remain informed about road conditions. The developer will work with WYDOT to discuss potential issues that could arise from maintenance employees directly changing the database and the best way to address those concerns.

1.2 Login Page

When the device is turned on, the app will automatically launch and show the default login page. The login page will have fields for the username and password. If possible, this will be tied to the WYDOT IT Active Directory system. If not, the password will be six digits set by the user. The log in will allow the users to customize the layout of the app so it is most useful for them. When a user logs in, it will send a 10-41 (beginning tour of duty) notification to the TMC. When a user logs out, it will send a 10-42 (ending tour of duty) notification to the TMC.

1.3 Default Homepage

The default homepage will allow maintenance employees to report real-time road and weather conditions. The homepage shows the 8 and 9 codes WYDOT uses. The 8 codes displayed are 8-1 (dry road), 8-2 (wet), 8-3 (slick), 8-4 (slick in spots) and 8-5 (drifted snow). A road closure recommendation (8-6) should be done over the radio. The 9 codes displayed are 9-1 (favorable conditions), 9-2 (snow), 9-3 (rain), 9-4 (strong wind), 9-5 (fog) and 9-6 (blowing snow) and 9-7 (reduced visibility).

This page will also allow maintenance employees to report black ice and to report if their vehicles are registering freezing temperatures. Black ice is the only advisory that will be reported from the app. All other advisories will either be handled by the TMC or called in. The app will have a feature that allows temperature readings from the vehicle to automatically be sent to the TMC; however, this feature will be disabled. Temperature information as measured by systems on the vehicle will not be automatically sent to the TMC. Rather, operators will report freezing temperatures after reading temperature gauges.

After the app has been idle for 30 minutes, it will automatically switch back to the homepage in real-time reporting mode.

1.4 10 Code Page

The Default Advisories/10 Code page will allow maintenance employees to report a number of 10 codes: 10-45 (animal carcass) 10-46 (motorist assist), 10-50 (crash) and 10-54 (livestock on

roadway). It will also include a button to allow operators to report a vehicle slid off the road and to report if there is lane blockage. This page will also allow users to report 10-7 (out of service) and 10-8 (in service).

This page will have limited function when in real-time mode. While in real-time mode, the user can send only location information to the TMC and follow up with information over the radio. When in post-report mode, the user can enter all the information typically provided to the TMC through the app.

1.5 Default Variable Speed Limit Page

The default VSL page will allow maintenance employees to see information about current VSLs for the segment of road on which they are currently located. They will also be able to recommend a change to a VSL for the two nearest sections. They will have the option to select a speed limit to be displayed on the sign for the section of road they are on, the previous section of road and the next section of road. Signs will be identified by mile marker. The speed recommendations will apply by default to the direction they are travelling and they will have the option to recommend applying the speed to both directions.

The default VSL page will include icons that list the current speed limit, the pace speed and the recommended speed as determined by an algorithm under development by WYDOT. If the vehicle is in a VSL section, these items will be pulled from WYDOT's database every three miles or every three minutes, whichever comes first. Beneath the icon that lists the current speed limit, there will be a timestamp for the last update and the name of the department that made the last recommendation.

The screen will also show icons representing all of the speed options for the segment of road. If the pace speed and the recommended speed are 10 mph more or less than the legal posted speed, the user will be alerted so he or she can make a recommendation.

1.6 Road Weather Information System Page

The default RWIS page will provide maintenance employees with information from the four closest RWIS devices. The information will automatically populate with the name of the RWIS, location, and time of last update. Information available from an RWIS includes air temperature, relative humidity, dew point, visibility, surface temperature, wind gust, wind average, and wind direction. A text to speech function will allow drivers to have this information read to them. The RWIS Page will automatically update every nine minutes or nine miles, whichever is first. The user can also click the RWIS page tab at the top of the screen for an update. When the vehicle is not moving, the user can press and hold an icon associated with an RWIS and the app will retrieve the last x number of records and plot histograms for available information.

1.7 Weather Radar Page

The default Weather Radar page will include a radar image loop of Wyoming and a district forecast. Because the bandwidth required for radar images to download, the radar image will update every time the device is connected to Wi-Fi or once every 10 minutes if the vehicle is within Wi-Fi range for a prolonged period.

1.8 Map Page

Using Automatic Vehicle Location equipment installed on most maintenance vehicles, iconic images of vehicles will be used to represent the location of every maintenance vehicle in the state, except some supervisor vehicles. Users will be able to turn on and off "bread crumbs" to show where the vehicles have been. While the statewide information will be available, when the page is first opened it will be zoomed in to a predetermined radius. The icon representing the vehicle's location will be centered on

the screen. When a maintenance employee reports 10-7 (out of service), the image of his/her icon will change color to indicate the employee might not be accessible by radio. When a user clicks on an image of a vehicle, a pop up will appear and a voice will display and/or speak the number of the vehicle selected and the name of the user who is signed in to the app being run from that vehicle. The map will also indicate when a road is closed.

The base map will be saved to the local machine, so it does not have to reload, thereby placing undo demands on bandwidth. It will include locations of sand piles, maintenance shops, locations of Wi-Fi hotspots and RWIS devices. WYDOT will have the ability to edit the base map. The graphics package used on the base map must be approved by WYDOT to ensure it can be edited.

1.9 Messages Page

The app will allow for limited message functions. Users will be able to receive messages from others who have the app with the messages page enabled. They will have the option to have the message read to them through a text to speech function. When the vehicle is stopped, users will be able to read messages and a keyboard will become functional to allow them to type messages.

The message page will also allow users to choose notifications they would like to receive. They can choose to be notified every time the database is updated with new road condition information for their location or for the maintenance section they are in, every time a dynamic message sign changes for the road section they are on or the road segment they are on, and when a VSL changes for the road they are on or the road segment they are on. The developer will work with WYDOT to arrive at an ability to extend notification options to additional items.

1.10 Dynamic Message Sign Page

The default DMS page will allow maintenance employees to view messages displayed on DMS along the segment of road they are working on, in addition to the closest DMS from the previous segment and the closest DMS from the next segment. The signs will be in order from lowest milepost to highest mile post. If the vehicle is in motion, this page will be disabled. The DMS Page will not automatically update. The user can click the DMS page tab at the top of the screen for an update. A timestamp on the page will show the time of the last update.

1.11 More Page

The app will allow for user customization. Users will be able to drag unused icons to the More page so they can be stored away from frequently used icons to reduce screen clutter. The More page will also be where users can access customization preferences, including the ability to restore settings to default, restore to settings in place at the last log in, set reminder preferences, and hide tabs at the top of every page.

1.12 Snow Performance Measures Page

In maintenance vehicles that operate in areas where employees must submit snow performance measure information, a page will be enabled that allows them to report pertinent information, including truck hours, man hours, the amount of salt/sand used in tons, the amount of liquid used in gallons, the amount of ice slicer used in tons, visibility estimates, road temperature estimates and snow accumulation estimates. Some of this information will be able to be collected automatically by WYDOT through existing systems in the vehicle.

1.13 Docked Icons, Tabs

Every page will include some of the same features. Across the top of the screen will be tabs to move from one page to another. While the app will also allow users to swipe from one page to the next, the tabs will provide another option to move more quickly across multiple pages and in some instances serve as a “refresh” button. The tabs will have default labels, but they will be customizable. Operators will have the ability to hide tabs.

Across the bottom of every screen the following icons will be docked: Emergency Call to have a Wyoming Highway Patrol trooper dispatched to the vehicle’s location, current reported road conditions, wind gust and direction, the posted speed limit if in a VSL zone, vehicle location by mile marker and route, GeoTag button and settings to allow the operator to switch between real-time and post reporting mode and to turn on and off audio.

If a user presses and holds the emergency call button for two seconds, an emergency notification will be sent to the TMC. The notification will include the time the button was pressed and the vehicle’s location by route, milepost, and direction of travel.

The current reported road conditions icon will show the road condition information stored in the database for the vehicle’s location and who last updated it. If the driver presses the icon and holds for two seconds, the road conditions for the road segment the driver is on will be recited.

Wind speed will include the wind gust and direction information reported by the nearest RWIS.

The posted speed limit will be the posted speed limit if in a VSL zone. If outside of a VSL zone, this icon will not appear.

Vehicle location will show the route and milepost for the vehicle.

The GeoTag button will allow the operator to save a position for future reference. When the employee hits the button, an icon will appear on the map page in the appropriate location and the location will prepopulate in Previous GeoTag dropdown menus. These tags will be saved until the operator logs out of the app.

The settings button will allow the operator to switch between real-time mode and post reporting mode and to turn audio on and off.

1.14 Supervisors Page

There was discussion about enabling features for use by supervisors, but it became apparent there wasn’t an immediate need. It is possible in the future that features will be added that can only be used by supervisors, but at this time WYDOT believes all features should be available to maintenance employees and supervisors.

2. App Functionality

This section details how the app will function in the field, customization options and controls.

2.1 Field Function

Wyoming Statute 31-5-237 prohibits the use of handheld electronic wireless communication devices for electronic messages, but provides several exceptions. It is our understanding, which has been vetted with the Attorney General’s office, that use of this app is allowable under the law because they will push buttons rather than type text. To comply with state law, any typing function will be disabled when the vehicle is in motion. Local laws will be reviewed to make sure use of the app does not

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violate rules put in place by local governments. If use of the app is in violation of local laws, use of the map in real-time mode will be limited to what is allowable. To encourage driver safety, voice control and audio cues will be implemented and encouraged to be used whenever possible. The contractor will work with WYDOT to identify ways to use voice recognition and text-to-speech functions whenever feasible.

The app will be designed in such a way that the functions of each default page can be limited on a device by device basis. This will allow for as much control on the district level as possible. This will allow a district maintenance engineer or foreman to decide whether functions should be limited on a specific device. It will also allow the app to be used by WYDOT employees who do not have permission to report road condition information or make recommendations to change VSLs.

2.2 Manual and Voice Controls

The purpose of this app is to make it easier for maintenance employees to report condition information and make recommended changes to VSLs, and to make the process of sharing that information with the public more efficient and timely.

To make the app as user friendly and safe to operate as possible, voice recognition software will be implemented so users can speak commands similar to what is now transmitted over the radio. These commands can be given with any page open, even if the corresponding icon is not visible. To improve the quality of voice recognition, voice recognition will be limited; the app will recognize spoken 8, 9 and 10 codes, and commands to recommend changes to VSLs. The system should allow new voice commands to be added and existing voice commands to be altered. For example, the user could say “Report 10-13” to indicate a road weather report will follow, then the appropriate 8 and 9 codes and the word “send.” When a user selects a button through the voice recognition system, the corresponding icon will turn yellow, similar to the way it will turn yellow if it is touched.

When a maintenance employee reports conditions for the roadway, either by manually selecting them or speaking them, those codes will “stick,” meaning they will remain selected, so the user only has to hit or say “Report 10-13, send” again in order for the same road conditions to be reported for a different segment of road or to report conditions have not changed on the same road segment. The user can click the button again to deselect or say “deselect” followed by the button. To hear the current reported conditions, the operator can say “Recite 10-13.”

2.3 Audio Notifications

To keep drivers’ attention on the roadway, the app will allow them to have road condition reports read to them. When the vehicle nears a road segment boundary, the app will audibly alert the driver to the road and weather conditions currently being reported for that location. When a driver approaches a VSL zone, he or she will audibly be told the speed limit for the area, the recommended speed and the pace speed. The system will also allow the operator to hear when road condition information is updated, when VSLs change and when messages posted on dynamic message signs change. In addition, road condition information can be heard on demand by pressing the road condition icon on the bottom of every screen or by stating, “Recite 10-13.”

2.4 Data Transmission and Retrieval

Because of limited cell phone coverage in Wyoming, the app will primarily rely on the WyoLink radio system for service. WyoLink is designed to be a voice priority system, so someone talking over the radio will preempt transmission of data. The system will be designed to store and forward user selections in the event of system queuing. We intend to transmit data over a channel that is not commonly used by radio traffic. This is expected to have the benefit of reducing time for data

transmission. By moving transmission of road and weather reports off the normal voice channels, it will clear it for emergency transmissions. Options to allow prioritization of data should be explored, so an emergency notification takes precedence over road condition and 10 code reporting.

The app will retrieve updated information as requested and vehicle location information every three miles or three minutes, whichever comes first. This will primarily be done through the WyoLink system. However, when the vehicle is within range of Wi-Fi, it will automatically join trusted networks. The app will test to make sure the connection is stable. If it is, the app will switch to Wi-Fi to retrieve updates, send any pending reports, and download updated radar images and forecasts if the existing information is more than an 10 minutes old.

There will be hotspots at locations that include sandpits, RWIS devices, ITS roadside devices or other locations to be determined. It is also possible the system will connect to Wi-Fi hotspots in Wyoming Highway Patrol troopers' vehicles.

2.5 Automatic Reminders

There are circumstances in which drivers will be prompted to make updates:

- If road condition information has not been updated for a predefined period selected by the user, an alert will sound, prompting him or her to send an update. The interval will be based on the time elapsed since the last update from maintenance for the vehicle location, not on the time elapsed since the user made an update.
- If the driver is in a VSL zone and the pace speed or recommended speed is more than 10 mph different from the posted speed limit, an alert will sound prompting the user to suggest a different speed.

Because maintenance employees have many tasks to complete, the pop up alerts can be dismissed. If an alert is dismissed without action being taken, another alert will sound in 20 minutes. When an alert is issued, the corresponding tabs and icons will turn red. They will remain red until an update has been sent, even after the pop up alert has been dismissed.

If the app has been idle for four hours, an alert will sound. If the driver does not take action to acknowledge the alert within 20 minutes, he or she will automatically be signed out. The system will shut off with the ignition.

2.6 Customization

Wyoming is a geographically diverse state, so some conditions commonly reported in District 5 could be seldom reported in District 1. To make the app user friendly, it will be customizable. Maintenance employees will sign in to the app using a user name and password.

Users will log in and out of the app and their settings will be saved. This will allow two drivers using the same device to have different views to reflect their personal preferences.

To customize the view, individual icons or, in some instances, groups of icons can be dragged from one page to the next. Some pages, like the Weather page, will have fixed content, but the order of the pages can also be customizable. So, if the vehicle is not in an area with VSLs, the user can drag that page so it appears last and doesn't interfere with navigation within the app. The user will also be able to drag icons for his/her most commonly reported road and weather condition information to one screen to make it easier to use.

Appendix C – Evaluation Plan

Evaluation Plan for the Wyoming DOT Weather Responsive Traffic Management (WRTM) Project

1.0 Introduction

The document describes the evaluation strategy for the Weather Responsive Traffic Management (WRTM) system implementation at the Wyoming Department of Transportation (WYDOT). This evaluation serves as a way to measure overall program impacts by outlining the four evaluation hypotheses, and details the methodology by which each will be tested, including data to be used. Data collection will occur throughout the season, and the evaluation process will begin during winter 2014/2015 using prior winter experiences as baseline.

1.1 Project Description

Reducing crashes and fatalities is a core mission for WYDOT. Adverse weather is a significant contributor to crashes and fatalities on the Wyoming State Highway System. WYDOT relies on timely and accurate updates to pre-trip and roadside systems to providing the driver with the best information possible during adverse weather.

The Traffic Management Center (TMC) in Cheyenne, WY acts as the nerve center for managing operations. During adverse weather conditions, the TMC plays a proactive but time-consuming role in receiving, verifying road condition information and then posting it to the traveler information channels.

In addition to traffic cameras and Road Weather Information Systems (RWIS), WYDOT relies heavily on maintenance employees to provide accurate, timely road condition information. Using a cell phone or radio, maintenance employees provide reports based on a standard set of road surface conditions (8 codes), atmospheric conditions (9 codes), and other conditions (10 codes). That information is relayed to the TMC where operators record the conditions, report the conditions to the public, and, if warranted, make adjustments to roadside devices, including variable speed limits, dynamic message signs, highway advisory radios, etc.

This project allows maintenance employees to make reports using an application (app) on a tablet computer installed in their maintenance vehicles. As a result, this project will minimize the manual involvement of the TMC in receiving, recording, and updating information systems where possible by linking field data collection directly into the traffic management systems. Utilizing the app, a richer set of road condition information will be available to the TMC at a greater frequency, and consequently to the travelers of Wyoming roads as well.

In addition to sending information to the central database, the app seeks to improve maintenance operations by providing maintenance employees with an in-vehicle weather forecast from meteorologists, information from RWIS, and information from roadside devices to help them better prepare for changing weather conditions.

Because cellular service in Wyoming is not available in all locations, and because monthly data contracts are expensive, the system will operate over the WyoLink radio system and over Wi-Fi, when available. WyoLink is a statewide digital trunked VHF P-25 compliant public safety communications system. WYDOT currently uses the system for radio communication and to transfer data. The app

will be used in a pilot project with participants from crews who work in two WYDOT maintenance districts along Interstate 80 and Interstate 25. System development is expected to begin in March 2014, with the app available for the upcoming 2014-2015 winter season.

1.2 Objectives of Evaluation

The analysis outlined in this plan (section 2.0) is designed to evaluate the following hypotheses:

- The application will improve the efficiency of condition reporting by maintenance employees and TMC Operators.
- The application will improve traffic management capabilities at the TMC during weather events.
- The application will improve the timeliness of condition reporting updates to the public.
- The application will improve situational awareness of maintenance and patrol employees.

1.3 Document Organization

The remainder of this report is divided into four sections. Section 2.0 outlines the evaluation approach, which includes detailed descriptions of how to test each of the four project hypotheses. Section 3.0 discusses data analysis. Section 4.0 lists the risks inherent in evaluating the program, as well as strategies to mitigate them. Section 5.0 outlines the evaluation schedule and provides an itemized action plan for evaluation preparation. Section 6.0 defines the roles and responsibilities of WYDOT staff and FHWA and their contractor (Battelle).

2.0 Evaluation Approach

The evaluation focuses on four hypotheses identified in Section 1.2 and expanded upon below.

2.1 Analysis Overview

The subsections below describe each hypothesis and the testing methodology in detail.

Hypothesis 1: The application will improve the efficiency of condition reporting.

At present, each radio or phone transaction is comprised of several steps. First, a maintenance employee must recognize a reportable event or condition on the roadway. Second, the maintenance employee must assess the current report to see if an update is necessary. This is not always possible without an additional call to the TMC because there are no current means of determining active reports aside from listening to and memorizing each road section report given over the radio. Third, if an event or road condition needs to be updated, the maintenance employee must find a safe and clear radio opportunity to make the report. Fourth, if a radio transmission is unclear or it requires a verbal repeat, such as a variable speed limit adjustment, the maintenance employee can expect to have additional dialogue with the TMC operator. Fifth, the TMC operator must be certain that the radio transmission is understood by the maintenance employee. Sixth, the TMC operator must document/record the radio transaction in a call database. Seventh, the TMC operator must identify roadside devices that require immediate attention. After important roadside devices are updated, the TMC operator takes an eighth step of updating the pre-trip information systems.

If successful, the maintenance app has the potential for minimizing or eliminating six of the eight current required steps for most reports. The need to call the TMC during the second (assessment) step will be eliminated because active road conditions will always be present to the maintenance employee. The maintenance employee will not need to find a clear radio opportunity in the third step because the system will manage the potential for data transmission conflicts. The fourth step, ensuring a clearly understood relay of information, will be completely eliminated by the maintenance app. This should reduce the number of misunderstandings and improve accuracy. Steps five (TMC

receiving the report), six (TMC recording the radio transaction) and eight (updating pre-trip information systems) will also be eliminated.

Other considerations related to expected radio use include:

- It is possible that radio availability may go up for those without the technology because the radio is being used less often by those with the technology.
- Maintenance staff typically listens to the radio traffic to understand what is happening around them by others in the field. This awareness helps them to perform their job more effectively. Less radio traffic expected (by those using the technology instead to make road condition reports) may make this approach (of “listening”) not as effective. Supervisors may need to use the radios to keep maintenance staff (without the technology) aware of their surroundings. Additional tablets deployed over time will solve this problem because the technology will keep them informed.

Hypothesis 2: The application will improve traffic management capabilities during weather events.

WYDOT’s Transportation Management Center (TMC) is evolving with additional tasks and responsibilities thrust upon the operators on a regular basis. This hypothesis tests if the app provides new ways of doing business in an effort to gain efficiency and improve operations during stressful adverse weather conditions.

The maintenance app is intended to minimize the manual and time-consuming roles required of the TMC operator. As noted previously, several steps in the process of recognizing, receiving, recording and relaying events to the public can be minimized or all together eliminated. Such efficiency gains should allow the TMC operators to focus on more timely decision-making in terms of providing motorist alerts, advisories through roadside devices as well as the road condition reporting systems (511 and website). Roadside traffic management actions may include setting of speed limits on the existing VSL system, road closures, wind warnings, and general alerts provided to travelers on Wyoming’s highways.

Additionally, as WYDOT works to meet state and federal requirements regarding performance measurement, an accurate measure of the severity of a given storm is important. To help develop the framework for the evaluation measures, several WYDOT crews have been tasked with reporting information related to snow performance measures. Reports from the maintenance app could facilitate the regular reporting of this information that will ultimately improve traffic management capabilities during weather events.

Hypothesis 3: The application will improve the timeliness of condition reporting updates to the public.

Current utilization of road condition information sources available through the Wyoming DOT’s website and 511 have clearly demonstrated the value especially during adverse weather when usage spikes. Traveler expectations continue to grow with respect to the quantity, frequency, and the quality of data provided. In addition to meeting the needs of those traveling in the state, WYDOT must meet the demands of the Federal 1201 (511) Rule.

The app is expected to improve the timeliness of condition reporting updates in the following ways:

- The app is expected to reduce the latency of road reports available on the 511/website since the maintenance employees might make more frequent reports via the app.

- The level of detail in terms of field codes available for reports will be more accurately recorded through the application and shared with the public.
- The precision of the road reports will improve through the ability to automatically geo-tag conditions

Hypothesis 4: The application will improve situational awareness of maintenance employees.

Maintenance workers have been requesting access to weather-related information in their vehicles for a number of years. The information not only allows them to predict where and when a storm will hit, it allows them to predict manpower and material needs. While WYDOT has historically provided maintenance employees with predicted information of likely road conditions via daily road section forecasts, maintenance employees are interested in near real-time radar images that will track the active storms. Other items of interest include location-specific alerts and advisories to the maintenance employees. The hypothesis tests if providing customized weather information through the app to the driver is viewed positively by the maintenance employees.

2.2 Data Overview

The evaluation is designed to use both quantitative and qualitative data to evaluate the hypotheses. Table C-1 below outlines the quantitative and qualitative data elements that will be used to evaluate each measure of effectiveness (MOE) for testing each hypothesis. Note that some MOEs support multiple hypotheses.

Table C-1. Linkage between Hypotheses, MOEs, and Data Elements

Hypothesis	MOE	Data Element
Hypothesis 1: The application will improve efficiency of condition reporting by maintenance employees and TMC operators	<ul style="list-style-type: none"> • Reduction in the time spent by TMC operators on radio with maintenance field personnel for road condition reporting. 	<ul style="list-style-type: none"> • TMC and Radio Logs • Survey of TMC Operators
	<ul style="list-style-type: none"> • Reduction in the time spent by TMC operators to document conditions into logs and traveler information databases. 	<ul style="list-style-type: none"> • TMC and Radio Logs • Survey of TMC Operators • Interviews with Maintenance employees
	<ul style="list-style-type: none"> • Reduction in time needed by maintenance employees to send road reports. • Increase in the number of reports and field codes reported by drivers using the app compared to those not using the app 	<ul style="list-style-type: none"> • Interviews with Maintenance employees
Hypothesis 2: The application will improve traffic management capabilities during weather events.	<ul style="list-style-type: none"> • Increase in the number of accepted maintenance field personnel updates for VSL and DMS • Perceived improvement in quality of reportable performance measures. • Reduction in time needed by TMC operators to update DMS, VSL and other devices to match road conditions. 	<ul style="list-style-type: none"> • TMC and Radio Logs • Survey of TMC Operators • Interviews with Snow Performance Measures Data Users
Hypothesis 3: The application will improve the timeliness of condition reporting updates to the public.	<ul style="list-style-type: none"> • Increase in update frequency of road condition reporting during storm events on app-enabled segments versus those without the app • Increase in timeliness of road condition reporting during storm events on app-enabled segments versus those without the app 	<ul style="list-style-type: none"> • TMC and Radio Logs

Hypothesis	MOE	Data Element
Hypothesis 4: The application will improve situational awareness of maintenance employees.	<ul style="list-style-type: none"> • Number of maintenance employees who feel more informed about weather conditions when on the roadways • Number of maintenance employees who feel the maintenance app is useful to their operations. 	<ul style="list-style-type: none"> • Maintenance application Vehicle Interface Analytics reflecting usage of features by employees. • Interviews with Maintenance employees

Quantitative data collection efforts will be finalized based on direction from WYDOT and the analysis approach selected, as determined by the number and percentage of maintenance vehicles to be equipped with the application by WYDOT district. These efforts are likely to focus on several analogous winter events in the 2013-2014 and 2014-2015 winter seasons for the selected WYDOT district(s). The evaluation team will work with the identified WYDOT district representatives to ensure sufficient data is received to conduct the analysis in a comprehensive manner. Additionally, qualitative surveys or interview guides will be developed for distribution or conducting, respectively, at the end of the 2014-2015 winter season to gather input from involved stakeholders.

In addition to the data listed in Table C-1, measures will be collected to account for other factors besides the maintenance app itself that could influence the evaluation results. First, winter weather severity measures will be monitored to control for any differences caused by dissimilar weather conditions that might impact the evaluation MOEs. Changes made to the maintenance app through the 2014-2015 winter season will also be logged in order to control for improvements made that could influence the MOEs during the evaluation period.

3.0 Data Analysis

This section presents the approach to evaluating the hypotheses presented above. Specifically, the approach to testing each hypotheses and/or drawing conclusions is discussed, including statistical and analytical processes and tools.

The evaluation will utilize both ‘with-without’ and ‘before-after’ methodology to effectively test the previously described hypotheses. Possible approaches for evaluating conditions are:

- A before-after comparison of selected similar winter events in two winter seasons from the same WYDOT district, where the maintenance application was installed between the seasons.
- A comparison of a WYDOT district that has the maintenance application with a district that does not by selecting similar winter weather events in the same season (or the same winter event, depending on the difference in conditions for the two districts).
- A “same-storm” comparison within a single WYDOT district between maintenance vehicles that are equipped and not equipped with the application.

It is likely that a hybrid analysis approach will be used that integrates two or three of these comparison types, depending upon data availability and WYDOT input to determine the most accurate and effective approach. It should be noted that the third comparison approach, while minimizing effects caused by looking at different winter events, is not likely to provide a full picture that is needed to adequately compare every data element since some stakeholders will be interfacing with both equipped and not equipped vehicles.

It is expected that quantitative data required in this evaluation is already being archived by WYDOT, and will be available to the evaluation team for the 2013-2014 winter season. This data can be used to conduct before-after quantitative analysis for similar weather events. Although data collection activities span the entire winter season(s), it is anticipated that only a subset of winter weather events will be selected for analysis. Immediately after the first significant winter weather event of the 2014-2015 winter season, the evaluation team will conduct a high-level analysis on the performance of the snow maintenance application.

A bulk of quantitative data analysis will require archived TMC Operator and Radio Logs. It is expected that these logs include time stamped data entries, including information for when messages are received and when DMS, VSL, HAR, and other devices updated for disseminating the information to maintenance employees and the general public via roadside signs and traveler information systems. These time stamps will be examined for differences in time with and without the maintenance app (both within the 2014-15 winter season, as well as comparisons between the 2013-14 and 2014-15 seasons) to accomplish various activities, and thus measure the efficiencies gained through use of the maintenance app.

The maintenance app itself features a touch screen for maintenance employees to log current road and weather conditions. Any entry is geocoded and the maintenance employee can choose to either send immediately or delay transmission in order to enter additional details at a stop. The maintenance employee can choose from a series of 8-, 9-, or 10-codes reflecting conditions that are shown in Table C-2. These entries will be used in the analysis of several MOEs, including whether additional and improved information is being logged that enhances traffic management capabilities. Maintenance employees will also be able to enter information for VSLs to reflect current weather conditions, as well as validate posted DMS messages.

Table C-2. Codes used by WYDOT that are available in the Maintenance App

8 Codes	9 Codes	10 Codes
1- Dry	1- Favorable	7- Out of service
2- Wet	2- Snow	8- In service
3- Slick	3- Rain	45- Animal carcass
4- Slick in spots	4- Strong wind	54- Animal on road
5- Drifted snow	5- Fog	50- Crash
6- Closed (Not using in app)	6- Blowing snow	46- Citizen Assist
	7- Reduced visibility	-

As available, information will be collected from the individual maintenance application vehicle interfaces to help determine the maintenance employees’ usage of the application. The maintenance application has a number of features that are customizable, and also provides alerts which require an action from the maintenance employee. This information could help identify the information most frequently requested, used, or dismissed by maintenance employees, and thus the most useful. Google analytics will be used to capture the items that are most used by maintenance employees.

In order for the evaluation to track the evolution of the maintenance application through the winter season, it is expected that the dates for implementing any modification or revision to the maintenance application or operations will be logged. Depending on the number of changes made through the winter season across the analyzed winter weather events, the evaluation may need to be subdivided to account for improvements made to the maintenance application that might likewise improve performance.

Numerous qualitative data will be used to support the findings of the quantitative data analysis. A series of surveys or interviews will be conducted for maintenance employees, TMC operators, and users of snow performance data to assess their perceptions of impacts of the maintenance application. These surveys and interviews will gather the user perceptions of timeliness for reporting, additional time for other activities, reduced stress levels, and increased awareness. Surveys or interview guides will be developed in late 2014 for approval and input by WYDOT before being conducted twice during the evaluation period. The first round will occur immediately after the training is completed for the app at the beginning of the winter to gather initial expectations and inherent bias towards the system. The second wave will be towards the end of the 2014-2015 winter season and capture the evolution of the perceptions on part of the drivers.

4.0 Risks and Mitigations

Table C-3 lists potential challenges and constraints that may complicate the evaluation and make it difficult to obtain the anticipated results, along with some strategies to mitigate the challenges.

Table C-3. Potential project challenges and constraints and strategies used to mitigate them.

Risks	Mitigation Strategy
There is a learning curve associated with any new technology. Maintenance employees might find the app more difficult to use at first. Similarly, TMC operators might take time becoming accustomed to new procedures.	The maintenance app should be complete well before the start of the winter season, giving maintenance employees time to become accustomed to it. WYDOT intends to perform training for maintenance employees and TMC operators prior to the 2014-15 season start. For maintenance employees and TMC operators, the first wave of survey questions will try to gauge whether they are becoming more comfortable with the technology.
The amount of time it takes for a roadside device or information system to be updated can be dependent on the expertise of the TMC operator. Because the TMC hires seasonal employees in addition to permanent, full-time employees, their experience level could impact timeliness.	Because the sample size likely will not be enough to make up for outliers, this will be noted in the evaluation and considered in any analysis.
Employees might not feel able to share criticism of a project supported by their supervisors.	Employees will have the ability to make anonymous comments.
The state's storm rating system is not yet complete. If it is not done before the next storm season, it may be more difficult to compare like storms.	If the storm measurement system is not in place, the meteorologist who works in the TMC will be asked to help identify like storms for comparison purposes.
It can be difficult to track the number of mistakes because they are not marked as such in an archive. Operators may be unaware when a mistake is made.	Though mistakes cannot be directly tracked, we may be able to discern that maintenance employee-to-TMC operator translation errors should be completely eliminated, as no "hand off" is required.
Collecting snow performance measures is a relatively new concept for WYDOT and not all maintenance employees are involved. The number of people who participate in this will be low.	This will be noted in the evaluation and considered in any analysis.
The TMC is trained to update roadside devices before pre-trip information because it is deemed more critical. This could impact timeliness comparisons.	This information will be kept in mind when performing the evaluation.
Some data needed from the 2013-2014 season may be unavailable for comparative analysis to 2014-2015 season data since the evaluation plan identifying data needs was developed after the data collection period.	The evaluation team will work closely with WYDOT representatives to identify usable data and alternatives where any identified data element is missing in order to perform a complete analysis.
Time-stamps may not be available in all data logs.	Time stamped data entries are essential for several MOEs to evaluate improved efficiency. Quantitative analysis will be severely impeded should time stamping not be possible, accurate, or synchronized across data logs. In this event, the evaluation will rely more on qualitative data.

5.0 Evaluation Schedule

The finalized Evaluation Plan will be completed in April 2014, and evaluation activities will begin June 2014, beginning with accessing data from the winter season 2013-2014. A detailed evaluation task schedule is shown in Table C-4.

Table C-4. Evaluation schedule by task

Task	Completion Dates
Complete Evaluation Plan	May 2014
Begin Limited Quantitative Data Collection for 2013-2014 Winter Season	July 2014
Quantitative Data Collection for 2014-2015 Winter Season	Oct 2014 – April 2015
Conduct Debrief and Offer Additional Training, as needed	[after first winter event]
Conduct Preliminary Quantitative Comparative Analysis	Oct 2014 – Dec 2014
Submit Preliminary Analysis Findings	Jan 2015
Conduct Quantitative Analysis	Jan 2015 – May 2015
Distribute Stakeholder Surveys	March 2015
Conduct Qualitative Analysis	April 2015 – May 2015
Submit Final Evaluation Report	August 2015

6.0 Roles and Responsibilities

The execution of the evaluation activities described in this plan will be a joint effort conducted by Wyoming DOT and the FHWA Technical Support Contractor (Battelle Memorial Institute). This chapter describes the responsibilities of each party.

The development of the Evaluation Plan was a joint effort by both parties. It describes hypotheses to be tested, measures of effectiveness to be used, and data collection needs. Using information from the WYDOT developed Operations Concept and several discussions with WYDOT project staff, Battelle prepared this document and it was reviewed and approved by WYDOT.

The execution of this Evaluation Plan will also be a joint effort. In general, the data collection will be the responsibility of WYDOT and the analysis and development of the evaluation report will be the responsibility of Battelle. Specifically, the responsibilities are outlined in Table C-5 below:

Table C-5. Responsibilities During Evaluation Plan Execution

Evaluation Activity	Wyoming DOT			Battelle		
	Primary	Secondary	Review	Primary	Secondary	Review
Present evaluation approach to WYDOT staff ahead of project rollout.			●	●		
Review and ensure TMC, radio, and system logs provide needed data.	●					●
Develop surveys and interview guides for TMC Operators and Maintenance employees.		● (1)	●	●		
Collect and provide TMC, radio and other system logs during evaluation period.	●					●
Collect and provide other needed data, per evaluation plan.	● (2)					●
Conduct surveys and interviews with involved WYDOT staff, per evaluation plan. Provide results.	●				● (3)	
Analyze data to test hypotheses and draw conclusions.		● (4)		●		
Document results in Evaluation Report.			●	●		
<p>Notes:</p> <ul style="list-style-type: none"> (1) Contribute input and questions for survey and interview guide development (2) Refer to Evaluation Plan, Table C-1 for examples of other needed data to support analysis of MOEs (3) Battelle will strive to be present during interviews as time and budget allows (4) Work closely with Battelle to analyze data and provide insights to the conclusions 						

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