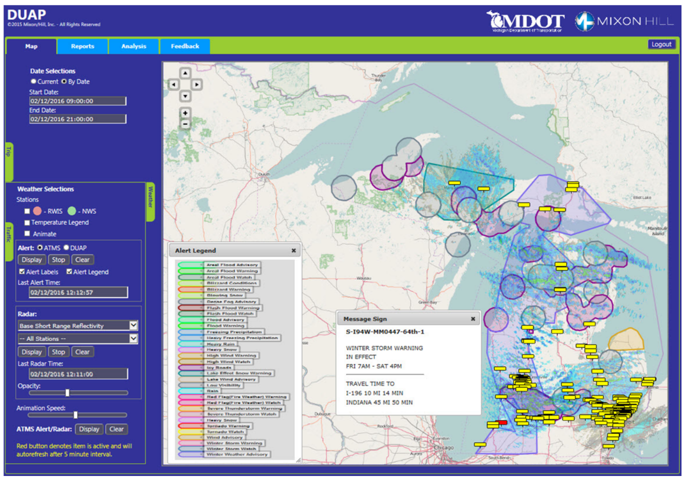
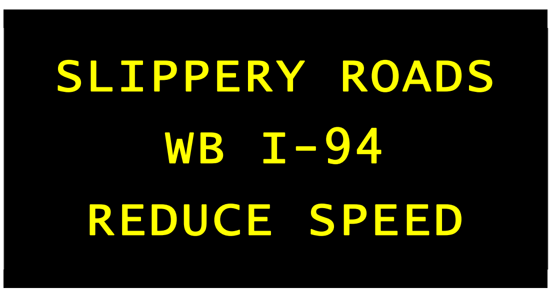
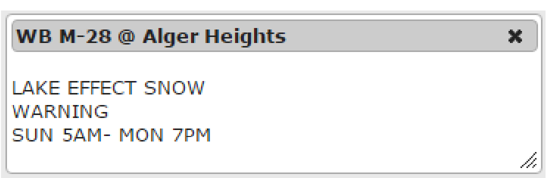
FHWA-JPO-16-323

Michigan Department of Transportation (MDOT) Weather Responsive Traveler Information (Wx-TINFO) System Implementation Project

Final Report – January 2016







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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. This report describes the system development, implementation, and evaluation of a recently completed Weather Responsive Traffic Management (WRTM) project in Michigan by the Michigan Department of Transportation. The MDOT Weather Responsive Traveler Information (Wx-TINFO) system brings together near real-time weather and environmental information collected from fixed and mobile data sources. The system processes the weather data and provides automated weather alerts and DMS message recommendations to Transportation Operations Center (TOC) Operators. The goal of Wx-TINFO is to integrate multiple weather data sources into a collective program that provides more accurate, timely, and effective messaging; thereby improving operating conditions during severe weather conditions. Overall, the evaluations indicate improved efficiency and effectiveness of traffic management activities during weather events. Furthermore, separate surveys of TOC Operators and the traveling public indicate that improvements in the system and traveler information were favorably perceived.

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Table of Contents

List of Tables

List of Figures

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 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. Specifically, this report describes the system development and implementation, and summarizes the evaluation of the Michigan Weather Responsive Traveler Information (Wx-TINFO) System.

Initial Implementation of the Michigan Weather Responsive Traveler Information System

The objectives of the Michigan WRTM Project are:

1. Improve the real-time traffic management capabilities of Michigan Department of Transportation (MDOT) Transportation Operation Center (TOC) staff during weather events
2. Improve the timeliness and content of road weather condition reporting updates to the traveling public
3. Provide road weather condition information that MDOT Maintenance staff perceive as valuable for possible use in future road weather maintenance operations

The initial WRTM project implementation included the development of a new Wx-TINFO System that provides near-time weather-related advisories and alerts that aid the traveling public in making more informed travel decisions to improve safety and mobility. The information for these alerts is generated by the Wx-TINFO system, which is deployed statewide and collects both fixed and mobile road weather data and processes that data to support traveler information and traffic operations.

Evaluation Findings

The initial implementation of the Wx-TINFO System was evaluated to assess its effectiveness and potential to improve Michigan's traffic management activities. The evaluation focused on three hypotheses associated with the objectives of the system described above. Table ES-1 shows the three hypotheses and summary of the primary results associated with each hypothesis.

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

Hypothesis	Summary of Results
1: The system will improve the real-time traffic management capabilities of MDOT TOC Operations staff during weather events.	• Six out of seven maintenance regions' operations during winter weather showed an increase in the average number and percentage of DMSs that display weather-related information during NWS Advisories and Warnings. • For DMSs that display weather-related messages during and up to three hours before NWS Advisories and Warnings, the advance notification time remains about the same if not slightly earlier for six out of seven maintenance regions. • In a survey of TOC Operators, about half had a favorable impression of the initial system. The provision of advance information was perceived as helpful, and some system changes were suggested. Adjustments were made to the system after the evaluation period to improve performance.

2: The system will improve the timeliness and content of road weather condition reporting updates to the traveling public.	• Mi Drive website visits increased by about 20 percent (associated with storms of one inch of snow or greater).
	• Mi Drive website DMS selections (mouse-clicks) was mixed—increased for three regions, remained constant for three regions and decreased for one region (associated with storms of one inch of snow or greater).
	• Travelers responding to the web-based survey indicated the following:
	  ○ They are familiar with weather-related DMS messages (76 percent)
	  ○ They responded to weather-related DMS messages by slowing down (65-87 percent) and/or changing trip plans (20-58 percent)
	  ○ They feel DMS improve safety (88 percent) and reduce delay (75 percent)
	• Weather-related messages during NWS alerts are more likely to contain specific alert terms and travel times, and fewer general announcements such as ICE AND SNOW TAKE IT SLOW and USE EXTREME CAUTION
	• Incident rate decreased for two regions, remained constant for two regions, and increased for two regions.
	• User delay costs during NWS Advisory and Warning alerts decreased statewide (25 to 67 percent).

3: The system will provide road weather condition information that MDOT Maintenance staff perceive as valuable for possible use in road weather maintenance operations.	• A limited survey of Maintenance staff indicates the value a Wx-TINFO system could provide during Maintenance operations. In general, roughly half of the respondents had a favorable opinion of the system potential, while others felt that the current system was fine. • Staff who supported the system citied the potential for improved accuracy and detail as the reason for increased value, while others perceived potential challenges with interpreting the large quantities of data, and potential distractions for maintenance vehicle drivers

Source: Battelle

Conclusions

The use of the MDOT Wx-TINFO system improves the real-time traffic management capabilities of its TOC Operations staff during winter weather events by displaying more weather-related messages with a slightly faster advance notification time. A majority of TOC Operations staff had a favorable perception of the initial system. Furthermore, early operator feedback led to system improvements. The benefits to travelers include more specific weather-related information messages and statewide decreases in user delay costs (UDCs) between 25 and 67 percent during NWS Advisories and Warnings. The web-based Mi Drive survey showed high ratings for familiarity with weather-related messages, responsiveness to weather-related messages, and overall perception of safety and efficiency.

The conclusion from the evaluation is that the initial Wx-TINFO system has proven to be successful in fulfilling MDOT’s project objectives, and several possibilities exist for additional improvements to support Traffic and Maintenance Operations. Future improvements may include adjustments to system thresholds, increased system automation, and the addition of other data sets to improve efficiency of messaging. The project was greatly successful in pulling together disparate fixed and mobile data sets and devising operations plans from those data. MDOT plans to continue enhancements to the Wx-TINFO system to improve WRTM strategies in Michigan.

Chapter 1. Introduction

Under the Road Weather Management Program (RWMP), one primary focus area of the Federal Highway Administration (FHWA) has been to encourage developing and implementing Weather Responsive Traffic Management (WRTM) strategies. The WRTM involves implementing 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. The WRTM also provides proactive advisories and control strategies based on forecasted weather conditions, and not just the impacts of those conditions.

In 2011, the FHWA RWMP initiated a project to document existing strategies for WRTM, identify improvements to the strategies, and develop implementable Concepts of Operations[1] (ConOps) for the improved strategies. Since then, the program has worked with transportation agencies in Utah, Oregon, Wyoming, Michigan and South Dakota to develop and implement advanced WRTM strategies using some of the concepts from the project. This report describes the system development and implementation and summarizes evaluation results for the WRTM project in Michigan.

1.1 Background – WRTM Program

Weather is one of many factors that affects traffic safety and mobility on roadways throughout the State of Michigan. Due to its climate, Michigan experiences a wide range of weather conditions throughout the seasons. In particular, snow and ice are known to affect the transportation system during the winter months. Such weather conditions can decrease roadway capacity and impact drivers' control over their vehicle, often resulting in increased travel time and crash risk. There are several methods by which Michigan improves roadway safety and mobility during adverse weather conditions, including conducting maintenance activities and posting advisories on Dynamic Message Signs (DMSs). Although maintenance crews work to maintain normal operating conditions, the location, timing, and content of the DMSs play a critical role in raising awareness about current and impending weather or road surface conditions. Making sure that traveler information systems are timely and accurate is key to increasing driver awareness, which then improves safety and mobility of motorists.

1.2 Project Overview

The MDOT Weather Responsive Traveler Information (Wx-TINFO) system brings together near real-time weather and environmental information collected from fixed and mobile data sources. Within the Wx-TINFO system, MDOT's Data Use Analysis and Processing (DUAP) system processes the weather data and provides automated weather alerts and DMS message recommendations to Transportation Operations Center (TOC) Operators. The goal of Wx-TINFO is to integrate multiple

[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

weather data sources into a collective program that provides more accurate, timely, and effective messaging; thereby improving operating conditions during severe weather conditions.

Prior to implementing the system, a ConOps was created.[2] It describes the existing system, provides justification for and the nature of changes to the system, proposes system concepts and operational scenarios, and includes a summary of expected impacts.

The MDOT Wx-TINFO project is intended to:

- Improve the real-time traffic management capabilities of MDOT TOC staff during weather events
- Improve the timeliness and content of road weather condition reporting updates to the traveling public
- Provide road weather condition information, which MDOT Maintenance staff perceive as valuable, for possible use in future road weather maintenance operations

Operations and maintenance staff and the traveling public have benefitted from the Wx-TINFO system. The MDOT TOC Operations staff improved agency efficiency and productivity by avoiding redundant data collection and processing activities. Also, they provided traffic information more quickly through the Advanced Traffic Management System (ATMS) to the traveling public via DMS and Mi Drive (the MDOT traveler information website). The traveling public reported improved safety and mobility. The MDOT maintenance staff expects to further improve the ability to identify road weather problem areas and respond even more proactively to weather events. This continued improvement will further assist drivers in making informed decisions.

1.3 Organization of the Report

The report sections that follow include details of the MDOT Wx-TINFO system, as well as descriptions of the implementation, operations, and evaluations conducted as part of this effort. The report is organized as follows:

- Chapter 2 contains the system description
- Chapter 3 contains details regarding system development and implementation
- Chapter 4 summarizes the evaluation approach
- Chapter 5 provides evaluation results
- Chapter 6 summarizes the conclusions and lessons learned
- Chapter 7 provides recommendations
- Appendix A contains a list of acronyms used in this report
- Appendix B contains the detailed evaluation plan for this project
- Appendix C contains the traveler survey that was administered

[2] MDOT, Weather Responsive Traveler Information System (Wx-TINFO) Implementation Concept of Operations, September 22, 2014, available at https://www.michigan.gov/documents/mdot/09-22-2014_Wx-TINFO_Concept_of_Operations_471193_7.pdf

Chapter 2. System Description

2.1 Wx-TINFO System

The Wx-TINFO system provides near-time weather-related advisories and alerts that aid the traveling public in making more informed travel decisions. The information for these alerts is generated by the Wx-TINFO system, linked to any DMS in the coverage area, and delivered to the ATMS automatically. The TOC Operators retain the ability to approve or override messages from the Wx-TINFO system, if deemed necessary. The system is made up of the following components discussed in this chapter:

- Data Ingestion/Data Sources
- Quality Assurance/Quality Control (QA/QC)
- Logic/Decision Tree Analysis
- Weather Event Creation
- Message Delivery

2.2 Data Ingestion/Data Sources

The data ingestion process involves collecting and storing data from all available DUAP system sources, as well as non-DUAP sources (e.g., other MDOT systems, applications, and external sources). Some files are collected or "pulled" from the sources, while others "push" files directly to the DUAP servers.

2.3 Quality Assurance/Quality Control (QA/QC)

All data goes through quality checking routines appropriate for the type of data. For instance, latitude and longitude coordinates are verified to make sure they are actual locations, specifically within the state of Michigan, including a small section of surrounding areas. Vehicle speeds must also fall within normal parameters (i.e., between 0 and 110 miles per hour [mph]).

Environmental/weather data undergo similar checks against historical values to ensure that temperatures, wind speeds, and other measurements are not beyond what is normal for Michigan and its surrounding areas during the specified time of year (e.g., a temperature of 90 degrees Fahrenheit [^{o} F] may be appropriate for August, but not for January). The DUAP system processes the appropriate initial checks before making the data available to other applications and systems.

For Wx-TINFO, other quality checking routines and algorithms geared specifically toward validating weather-related data are used. Some of these algorithms have been successfully used in other initiatives such as *Clarus*, developed by the FHWA, and are utilized as-is.

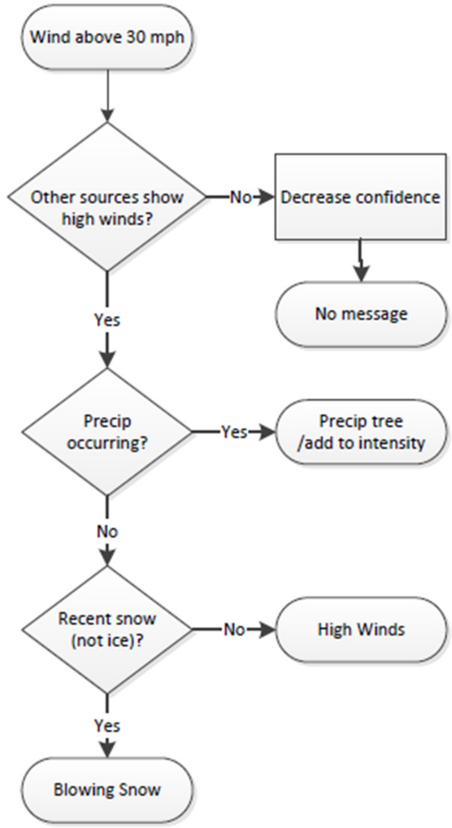
2.4 Logic/Decision Tree Analysis

Logic in the form of written codes and decision trees provide mechanisms for checking data as it arrives into Wx-TINFO. Weather conditions can change quickly, especially in the winter months, so it is important to have continuous processes running to monitor data as it is received. Decision trees, previously vetted with MDOT subject matter experts (SMEs), ensure that the confidence levels are high in the weather event information generated by the Wx-TINFO system.

Certain observation types are considered triggers for initiating a decision tree process, a surface temperature below 32º F, or a wind speed above 30 mph, for example. Each decision tree begins with a certain observation and identifies a specific weather event.

It is important to note that confidence is a significant factor in creating accurate weather event messages. The confidence levels are achieved by the system's ability to cross-check real-time data from multiple sensors and checking the sensor data against a set of pre-established logic. For instance, if only one sensor is reporting a wind gust speed of 60 mph and no precipitation or recent snow is detected by the same or neighboring stations during a winter month, the system uses the pre-established logic to determine whether this is sufficient for generating a weather event message. By following the logic defined in the triggered decision tree, the situation in this example would not result in generation of a DMS message. MDOT stakeholder input was crucial for creating decision trees, associated logic, and messages that appear on DMSs.

New data sources, additional sensors in the system, and advances in technology increase the availability of data. As data availability increases, additional (and potentially more complex) decision trees will be essential to maintain the confidence levels while processing the data and ensure the accuracy of the information that is fed into the system . A sample decision tree for a "Blowing Snow" weather event is shown in Figure 2-1.



Source: MDOT

Figure 2-1: Decision Tree for "Blowing Snow" Event

2.5 Weather Event Creation

The weather event identified at the end of a decision tree is the basis for creating a weather event file/message. The Wx-TINFO system creates a Keyhole Markup Language (KML) file with attributes such as a weather event identifier (ID) for tracking purposes, the weather event itself (in this case "Blowing Snow"), event beginning and end times, latitude and longitude coordinates for the affected area (polygon), status ("New," "Existing," or "Closed"), and suggested message text for the ATMS Operator's use in posting information to the roadside DMS.

The suggested message text follows the format suggested in the FHWA "Guidelines for Disseminating Road Weather Advisory and Control Information"[3] and MDOT's internal "DMS Weather Messaging Guidelines."[4] These documents suggest using three parts of information as is illustrated in Table 2-1.

[3] FHWA, Guidelines for Disseminating Road Weather Advisory and Control Information, June 2012, FHWA-JPO-12-046, available at http://ntl.bts.gov/lib/45000/45600/45623/FinalPackage_JPO-12-046_V1.pdf
[4] Internal MDOT document, not publically available.

Table 2-1: DMS Message Text Examples

DMS Information Parts/Lines	Message Text Examples
Problem/Weather Event	“BLOWING SNOW”
Location	“AHEAD” or “IN AREA”
Action	“TAKE CAUTION” or “REDUCE SPEED”

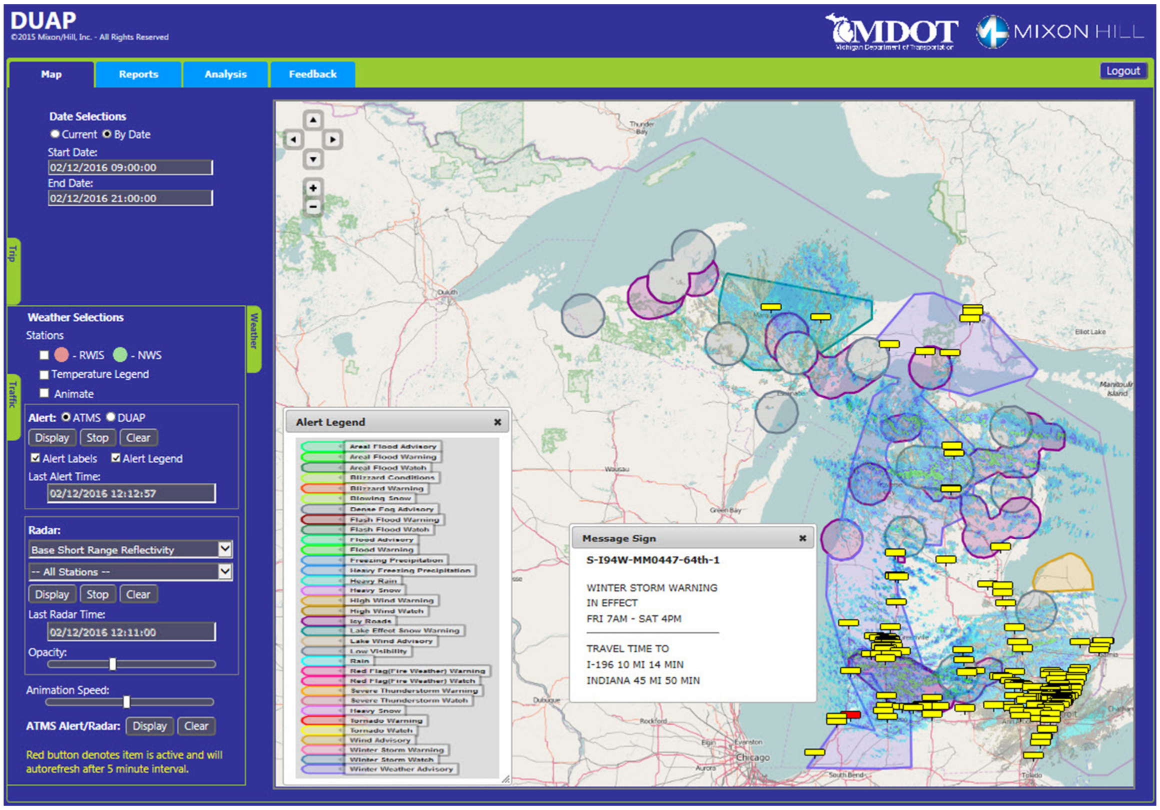
Source: MDOT

The Wx-TINFO and DUAP systems continuously run the data ingestion, parsing, quality checking, validating, and ensuring decision tree processes in order to create the weather event messages. These messages are compiled and a file is created in five-minute intervals. Files are not exclusive to events; therefore, one file could potentially contain more than one weather event.

If a weather event moves, but nothing else changes, the weather event ID remains the same, and the status changes from “New” to “Existing.” The ATMS Operator will not have to make any changes unless a specific DMS message needs to be changed due to a new condition or event that has recently occurred. If the severity or intensity changes, then the weather event is regenerated with a new event ID, and the original event ID changes to a “Closed” status. The original event continues to appear in the file for 30 minutes after the event’s ending time to make sure the operator has noted the “Closed” status and clears any affected DMSs.

2.6 Message Delivery

When the file creation is complete and contains all appropriate weather events for the five-minute period, it is moved to a server ready for collection by the ATMS. Once ATMS ingests the data file, the operator is notified of new weather events. The operator has the opportunity to review the new message and the DMSs to which it will be applied. The operator can use the suggested message, or override it based on other current events or circumstances. The message is then placed into the queue based on the event/alert subtype (including any changes made by the operator), and then posted to the appropriate DMSs covering the affected area. The ATMS determines which signs display the message, based on the geographic area specified by the weather event in the data file, an example of which is shown in Figure 2-2.



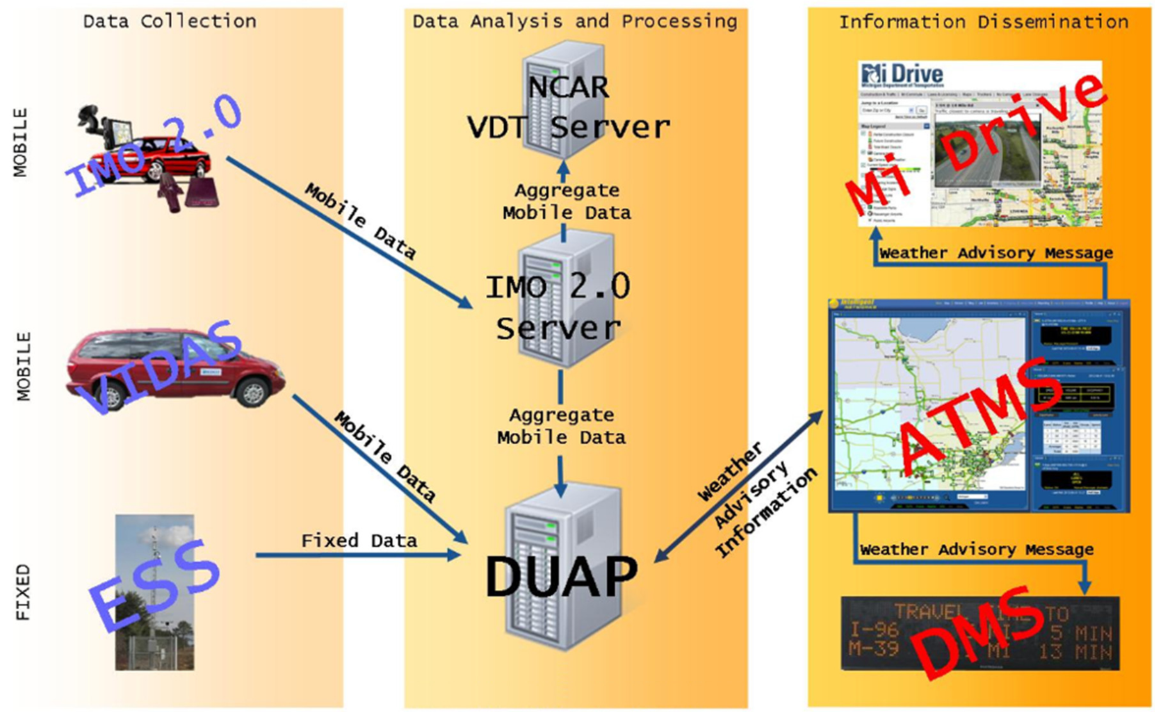
Source: MDOT

Figure 2-2: DUAP/ATMS Weather Mapping Example

As a weather event moves across the state, ATMS dynamically determines which signs show the message, as long as the original message was approved. Once the event has ended or moved out of the state, ATMS removes the message from the signs.

2.7 Data Sources

The Wx-TINFO system utilizes multiple data sources of different file types and formatting structure as shown in Figure 2-3. Each source for Wx-TINFO is described in more detail in the following subsections.



Source: MDOT

Figure 2-3: Wx-TINFO System Diagram

2.7.1 Integrated Mobile Observations (IMO)

The IMO is a project funded by the FHWA RWMP. The MDOT is one of three agencies involved in the project—Minnesota Department of Transportation (DOT) and Nevada DOT are the others. The University of Michigan Transportation Research Institute, alongside its partners, is the contractor developing the systems to gather mobile road condition data from snowplows, and light- and medium-duty state vehicles. The project in Michigan involves 60 vehicles equipped with special sensors utilizing smartphone technology to collect atmospheric and relevant pavement condition data. These data are sent via cellular communication to a back-office database. Additionally, data from the vehicle controller area network (CAN bus), such as wiper status, are collected and stored for analysis.

The data consist of elements such as latitude, longitude, altitude, heading, vehicle speed, brake activation, antilock braking system activation, traction control system events, and surface and ambient air temperature. Currently, the vehicles' most frequently traveled routes are along the Michigan I-94 corridor. Expanding this coverage area and/or increasing the number of equipped vehicles could provide additional valuable data for Wx-TINFO.

2.7.2 Environmental Sensor Stations (ESS)

MDOT ESS system deployments include the Road Weather Information System (RWIS), Automated Weather Observation Systems (AWOS), and Automated Surface Observation Systems (ASOS). MDOT's successful RWIS program is a valuable data source. Available in the data feeds are atmospheric and surface elements such as air temperature, dew point temperature, precipitation rate and amount, relative humidity, visibility, wind speeds and direction, surface freeze point, surface temperature, and chemical factors. The MDOT Office of Aeronautics manages AWOS and ASOS, which are installed at airports across the state. They provide weather observations 24 hours a day without human involvement. The systems report wind, ceiling, visibility, temperature, dew point, altimeter setting, and any recorded remarks. Those systems with "present weather" sensors also report certain precipitation types.

2.7.3 Advanced Applications of Connected Vehicle Data Use Analysis and Processing (DUAP)

The DUAP system is a source of many types of data. All of the data ingestion and processing power of the DUAP system can be exercised to support Wx-TINFO. The DUAP system is designed to collect disparate data sets, perform numerous data quality checking routines, and parse data files into meaningful information for storage in its canonical form for easy use in other MDOT applications and systems. The DUAP system also has security processes that maintain secure data environment.

2.7.4 Vehicle-based Information and Data Acquisition System (VIDAS)

The purpose of MDOT's VIDAS initiative is to develop, install, and demonstrate the capability of collecting road condition data using readily-available sensors (e.g., accelerometers/gyroscopes and Global Positioning System [GPS] locators) on vehicles. The flexible and expandable design provides the capability to use collected data over a sustained period of operations. Initially, a small number of MDOT fleet vehicles will be deployed and collect data elements such as accelerometer readings, GPS coordinates, surface and ambient temperature, wheel and vehicle speeds, and humidity levels. As the program continues and the fleet number increases, VIDAS can become a more important source of data for the Wx-TINFO system.

2.7.5 National Weather Service (NWS)

Ingestion of NWS data can provide a significant base of weather information for Wx-TINFO. This source offers additional sensor readings and radar imagery, along with text-based messages relaying warnings, alerts, and advisories. Table 2-2 shows a selection of NWS-based data elements that can be utilized within Wx-TINFO.

Table 2-2: NWS data elements that can be utilized within Wx-TINFO

Sensor Readings	Watches/Advisories	Warnings	Imagery/Radar
Air Temperature	Tornado Watch	Tornado Warning	Composite
Dew Point Temperature	Wind Advisory	High Wind Warning	Short Range (base reflectivity)
Heat Index	Winter Storm Watch	Winter Storm Warning	Long Range
Visibility	Lake Wind Advisory	Blizzard Warning	Storm Motion
Wind Gust Speed	Severe Thunderstorm Watch	Severe Thunderstorm Warning	1-Hour Precipitation
Weather Condition	Areal Flood Watch	Areal Flood Warning	Total Precipitation

Source: MDOT

Chapter 3. System Development and Implementation

The Wx-TINFO application was planned and designed with input from MDOT Operations personnel. The MDOT Intelligent Transportation Systems (ITS) Program Office met with Operations personnel to discuss integrating a weather alert system into the existing ATMS. The team used the system engineering process to rapidly develop the system and meet an aggressive project timeline. The project team worked closely to develop the ConOps. Working iteratively with SMEs, the team developed the project needs and system requirements. This information was the basis for designing and testing the application. System testing was performed dynamically with MDOT Operations staff who provided feedback for further application iterations.

Once consensus was reached on the design, the new functionality was incorporated into the DUAP system and ATMS as the Wx-TINFO application.

3.1 Application Development

The DUAP system's existing capabilities are integral to developing the new Wx-TINFO application. These include the ability to ingest and quality check a variety of fixed and mobile data sources, including data from connected vehicles and the MDOT fleet. The DUAP system provides operators with background weather information that can be used to verify and validate weather alerts generated for ATMS. The system development contractor, Mixon Hill, Inc. worked with MDOT to develop the Wx-TINFO functionality for the WRTM implementation project.

Wx-TINFO added the following new functionality to DUAP and ATMS.

- Consolidate weather information from a variety of sources to obtain a more detailed view of the current conditions
- Locate weather events requiring alerts to be sent to the traveling public
- Send events to ATMS for propagation to affected DMSs and the Mi Drive website—Mi Drive is a map-based traffic and construction information resource center website [5]
- Update DMSs based on weather event changes
- Provide quality checking and quality assurance functionality for validating data including, but not limited to, spatial and step comparisons
- View weather data and events historically
- Ingest DMS information to provide feedback for what was displayed for a given weather event

The new functionality of the DUAP system is configurable for ongoing tuning and improving weather event reporting, helping ensure the accuracy and confidence of the information conveyed to the public.

[5] Mi Drive website available at http://mdotnetpublic.state.mi.us/drive/

The application was tested for two months by the Operations staff, and their feedback was used to tune the algorithms employed by the application. The current version of the application was deployed in January 2015. Since that time, ongoing feedback from the Operations staff has helped guide operating system enhancements, ensuring the weather events are being reported accurately.

3.2 Testing

MDOT and the system development contractor worked closely to test the functionality of Wx-TINFO application. The team monitored weather and associated alerts to verify that the weather events were reported correctly. Based on the system requirements, the team used DUAP to verify the functionality of the system changes by inspecting closed-circuit television images, NWS radar and observations, and RWIS observations. Analyzing the weather-related data assured the quality of the weather event data that were sent to ATMS.

Frequent feedback from MDOT operators throughout the process allowed developers to integrate and test modifications. This process commenced in November 2014 and continued after deployment throughout the 2014–2015 winter season.

Analysis of the functionality continued to be investigated after deployment to assist in determining future needs of the system.

3.3 Other Supportive System Developments

Feedback from the TOC Operators allowed modifications to be incorporated quickly to allow comparisons of changes within the same winter season. Some modifications included:

- Adjusting the merging of neighboring winter weather events
- Tuning algorithm thresholds to adjust the level of which events were reported
- Modifying algorithms to report events more accurately

3.4 Staff Training

Having SMEs involved in all phases of the project was integral to meeting the requirements of the system and ensuring usability for the operators when it was deployed. A session was held with the TOC Lead Operators to explain and demonstrate the functionalities within DUAP and the changes to ATMS. The information was then propagated to the rest of the operators and field personnel. Frequent MDOT training webinars were attended by the Lead Operators before and after deploying system changes to ensure all changes were understood and met MDOT’s needs.

3.5 Implementation/Deployment

Modifications to the DUAP system allowed the TOC Operators to view detailed information concerning the weather events being reported by DUAP through ATMS. This provided verification of the weather alerts prior to promoting them to the affected DMSs. Deploying coordinated changes to DUAP and

ATMS allowed the operators in all of MDOT's TOCs to receive the weather alerts as they were generated, along with the detailed weather information triggering the alerts.

Chapter 4. Evaluation Approach

4.1 Evaluation Hypotheses

A project evaluation document was developed during the project planning phase (see Appendix B) with the goal of investigating the following three hypotheses:

1. The system will improve the real-time traffic management capabilities of MDOT TOC Operations staff during weather events
2. The system will improve the timeliness and content of road weather condition reporting updates to the traveling public
3. The system will provide road weather condition information, which MDOT Maintenance staff perceive as valuable for possible use in road weather maintenance operations

Each hypothesis is comprised of one or more Measures of Effectiveness (MOEs), which are summarized later in this chapter. Project success, defined by achieving MOE targets, is highly dependent on disseminating weather-related messages to the public. Thus, it is important to understand the methods by which messages are generated and how the system is designed to communicate with the public, as described in Chapter 3. The DUAP system aggregates and synthesizes data from mobile and fixed sources to identify weather events and generate recommended messages related to the subject weather event.

The DUAP alert is presented to TOC Operators along with recommended messages for DMSs in the affected area. Ultimately, the message content and decision to post it is decided by the TOC Operator. Once posted to a DMS, the message can be viewed in one of two ways, while driving past the DMS, or on the Mi Drive website. In order to view this information on the website, visitors must first activate the Message Signs map layer. Once activated, the user can click on any icon (representing the DMS board) to view the message that is currently posted on the selected DMS.

4.2 Data Sources and Analysis Methods

Several data sources were identified in the evaluation plan and the following data items were acquired:

- DMS Messages (November 2013 through April 2015)
- DMS Inventory
- Incidents (November 2013 through April 2015)
- NWS Alert Data (January 2013 through July 2015)
- Spatial Data for Michigan State-owned Roads
- Wx-TINFO/DUAP Alerts (November 2014 through April 2015)
- Wx-TINFO/DUAP Alerts to DMS asset link file
- TOC Operators Survey (May 2015)

- Maintenance Staff Survey (May 2015)
- Mi Drive Survey Data (April 2015 to May 2015)
- User Delay Cost (UDC) Data from the Regional Integrated Transportation Information System (RITIS) (November 2013 through April 2015)
- Mi Drive logs and usage statistics (November 2013 through April 2015)

The analysis methods used to assess each MOE are also defined. Types of analysis methods used in a study such as this one include before-and-after analysis, with-without analysis, and causal analysis.

Before-and-after comparison – This analysis assesses MOEs for two different time periods to determine in which time period the system was more effective. In the case of the Michigan WRTM project, the most important MOE comparison is before and after the Wx-TINFO project was implemented. The project was implemented during the 2014–2015 winter season, therefore data from both winter of 2013–2014 and winter of 2014–2015 were used in the before-and-after comparisons. The time periods for the before-and-after period are as follows:

- **"Before" implementation—or "pre-deployment"—**evaluation period occurred from November 1, 2013 to April 30, 2014 plus November 1, 2014 to January 14, 2015.
- **"After" implementation—or "post-deployment"—**evaluation period occurred from January 15, 2015 to April 30, 2015.

These unequal time periods (extended pre-deployment period and shortened post-deployment) were used because the deployment date occurred in the middle of the 2014–2015 winter season. The evaluation controlled for these unequal time periods when necessary by using percentages rather than raw totals.

With-without analysis – Similar to the before-after comparison, this analysis technique assesses MOEs for two different time periods. However, the time periods are defined by a given event that needs to be controlled. For instance, whether or not a winter storm is present is an important factor for determining if a given MOE is being met. Other potential impacting factors include whether or not a storm occurs overnight or during daylight hours, and the area that a storm impacts.

4.3 Summary of Hypotheses, MOEs, and Data Elements

Table 4-1 summarizes the hypotheses, MOEs, and the data elements used to assess each MOE. Different combinations of the analysis methods listed above are used to transform the data elements into the MOEs. Whenever possible, MOEs are used to describe impacts that were brought about by implementing the system. The following chapter will describe the specific methods and analyses used to obtain each MOE.

Table 4-1: MDOT WRTM Project Evaluation Hypotheses, MOEs, and Data Elements

Hypothesis	MOE	Data Elements
Hypothesis 1: The system will improve the real-time traffic management capabilities of MDOT TOC Operations staff during weather events	• Increased number of reported significant weather events	• NWS Alerts • ATMS Log: DMS Messages • DUAP Alerts
	• Decreased response time to post and update travel impacts due to weather events	• NWS Alerts • ATMS Log: DMS Messages
	• Improved perception of value by TOC Operators	• Survey of TOC Operators
Hypothesis 2: The system will improve the timeliness and content of road weather condition reporting updates to the traveling public.	• Decreased time for travelers to receive and respond to travel impacts due to weather events	• NWS Alerts • ATMS Log: DMS Messages • Mi Drive Website Usage Data
	• Improved perception of road weather information value from travelers	• Traveler Perception Survey
	• Increased specificity of traveler information due to weather events	• ATMS Log: DMS Messages
	• Reduced incidents and crashes during weather events	• ATMS Log: DMS Messages • ATMS Log: Incidents • RITIS Data: Incidents • NWS Alerts
	• Decreased travel delays during weather events	• Delay Data • NWS Alerts
Hypothesis 3: The system will provide road weather information, which MDOT Maintenance staff perceive as valuable, for possible use in future road weather maintenance operations.	• Perception of capability value by Maintenance staff of weather condition information provided	• Maintenance Staff Survey

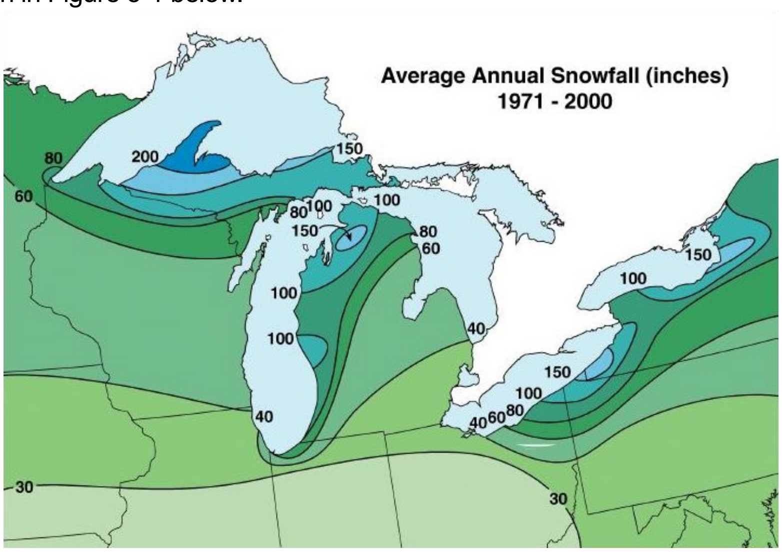
Source: Battelle

Chapter 5. Evaluation Results

5.1 Background

The severity of a winter weather event is expected to impact several MOEs. Because weather varies from year to year and storm to storm, the analysis accounts for the duration of winter weather when comparing MOEs in a before-after analysis using data from multiple years.

Variances in the spatial distribution of weather also make the analysis process more complex. Not only do certain areas exhibit more severe weather than other areas on average, but how a given storm impacts different areas is expected to vary greatly—storms can be widespread or localized, so can be their impacts. The lake-effect snow phenomenon is a prime example of spatial variance issues faced when working with winter weather data. Because it borders four of the five Great Lakes, Michigan is susceptible to lake-effect snow, which can occur in most locations across the state. Lake-effect snow storms can be a particularly localized phenomenon, where heavy snowfall is observed in narrow bands with clear weather conditions only a few miles away. Heavy accumulations (due to lake-effect snow) are most noticeable in the Snow Belt regions along the Lower Peninsula Lake Michigan shoreline and the Upper Peninsula Lake Superior shoreline. This spatial trend for the average annual snowfall is shown in Figure 5-1 below.



Source: Wikipedia

Figure 5-1: Michigan Average Annual Snowfall (inches) 1971-2000 [6]

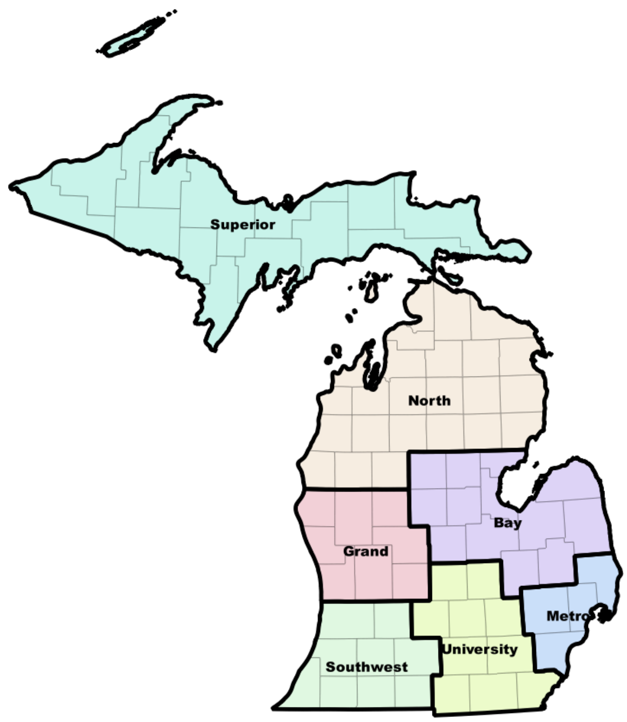
[6] Wikipedia. https://en.wikipedia.org/wiki/File:MichiganSnowfall.png

5.2 Data Overview

As described in Chapter 4, several data sources were identified to assess each MOE. This section is intended to provide the reader with an understanding of the type and quantity of data available and allows the reader to recognize the complexity of factors that are controlled when assessing MOEs. In order to do this, the following subsections provide a description of the data, data summaries, descriptive statistics, and/or visualizations for each data source.

5.2.1 Michigan Counties and Regions

Michigan is comprised of 83 counties, and seven maintenance regions which are made up of groups of contiguous counties. Many factors vary between counties, including but not limited to weather severity, population, traffic volume, highway lane-miles, and number of DMSs. These factors have the potential to influence assessment results from one county to the next. Data are aggregated at the statewide, region, or county level. The map in Figure 5-2 shows county boundaries and the maintenance regions.



Source: Battelle, data from MDOT

Figure 5-2: Michigan Counties and MDOT Maintenance Regions

5.2.2 DMS Inventory

The DMS inventory file includes spatial information about each DMS, as well as a location description based on road names. A data field from the inventory dataset is linked to data from the DMS messages dataset, which identifies the location of DMS messages. Figure 5-3 shows the DMS locations and totals within the MDOT maintenance regions.

Region	Number of DMSs
Bay	9
Grand	26
Metro	92
North	5
Southwest	18
Superior	8
University	23
Total	181
Points on image may overlap	

Source: Battelle, data from MDOT

Figure 5-3: DMS Locations and Totals within the MDOT Maintenance Regions

5.2.3 DMS Messages

These data files include information regarding the messages posted to each DMS in Michigan, and the time at which the message was posted. The data for most regions (excluding Metro) contain DMS Priority Queue records that indicate when a message expires and the DMS returns to a blank state. Otherwise, messages that are not followed by a DMS Priority Queue record are assumed to be displayed until replaced by a new message. Because DMS Priority Queue records do not exist for the Metro Region, a maximum message display time of one day is imposed.

Messages in these files are not specific to weather, and are filtered to obtain weather-related messages. Also, these files are linked to the DMS Inventory file using the Device ID field, which identifies the location where the message is displayed.

Inspection of all messages from the pre-deployment and post-deployment evaluation periods yields a total of 20 weather-related search terms. A list and count of messages containing these weather-related search terms is in Table 5-1. Any message that contains one or more of these words is considered a weather-related message. It is these messages upon which drivers are expected to react. Note that the search terms are not exclusive to a given message; therefore, multiple search terms can appear in a message (e.g., freezing rain, winter weather), and the search does not take the duration of the alert into account. Also note that changes in weather-related term usage may reflect changes in operational procedures, rather than changes due to the new Wx-TINFO system.

Table 5-1: Breakdown of the DMS Message Posting by Weather-related Search Term

Message Term	Pre-deployment Period Uses (in 8.5 months)	Post-deployment Period Uses (in 3.5 months)
BLIZZARD	0	186
BLOWING/DRIFTING	10	2
FOG	0	2
FREEZING	1,432	0
GUSTS	2	0
ICE	12,119	2,004
ICY	2,168	53
PRECIP/PRECIPITATION	0	1,797
RAIN	1,451	50
SLIPPERY	27,727	8,035
SNOW	13,068	5,061
STORM	26,583	13,612
TORNADO	0	19
VISIBILITY	0	335
WEATHER	27,613	24,339
WET	548	2,298
WIND/WINDS	753	7,449
WINTER	51,425	37,222

Source: Battelle, data from MDOT

5.2.4 NWS Alerts

A geographic information system (GIS) shapefile consisting of all NWS alerts (also called products) issued from 2013 through 2015 was obtained though the Iowa Environmental Mesonet, managed by Iowa State University[7]. This GIS shapefile of historic NWS products contains information regarding type of alert and the date and time the alert was active. Also included is the Valid Time Event Code—a concise and unique way of describing NWS alerts. In operational usage, the spatial attributes of this NWS alert data play an important role in determining when and where winter weather conditions are expected to occur or are actively occurring. In the evaluation, this information shows if weather-related messages were posted during weather events and controls for the storm durations between the pre-deployment and post-deployment evaluation periods in the analysis.

The timestamp of each NWS alert is given in Coordinated Universal Time (UTC) and is converted to local time in order to align it with other types of data (described in other sections of this chapter) that are stored in local time of the event. Most Michigan counties adhere to the eastern time zone, but a small portion of the state in the Upper Peninsula (Gogebic Iron, Dickenson, and Menominee Counties) adheres to the central time zone. Also, daylight savings time affects the NWS alert time conversions. Table 5-2 lists all of the applicable conversions from UTC to local time for the duration of the study.

Table 5-2: UTC to Local Time Conversions

Date Range (UTC)		Conversion for Eastern	Conversion for Central
From	To		
11/1/13 04:00	11/3/13 07:00	UTC -4 (EDT)	UTC -5 (CDT)
11/3/13 07:00	3/9/14 07:00	UTC -5 (EST)	UTC -6 (CST)
3/9/14 07:00	11/2/14 07:00	UTC -4 (EDT)	UTC -5 (CDT)
11/2/14 07:00	3/8/15 07:00	UTC -5 (EST)	UTC -6 (CST)
3/8/15 07:00	5/1/15 04:00	UTC -4 (EDT)	UTC -5 (CDT)

Source: Battelle

Table 5-3 breaks down the types of weather alerts by watch, advisory, and warning, and lists the total time-space each weather alert was posted for the pre-deployment and post-deployment evaluation periods. Table 5-3 also includes the weather events or phenomena that warrant issuance of different alert types. Differences between the three alert significances are listed below.

Watch – A watch is used with the risk of a hazardous weather or hydrologic event has increased significantly, but its occurrence, location, and/or timing is still uncertain. It is intended to provide enough lead time so that those who need to set their plans in motion can do so. [8]

Advisory – An advisory highlights special weather conditions that are less serious than a warning. They are for events that may cause significant inconvenience, and if caution is not exercised, it could lead to situations that may threaten life and/or property.

[7] Iowa Environmental Mesonet, available at https://mesonet.agron.iastate.edu/request/gis/watchwarn.phtml
[8] National Weather Service alerts definitions available at http://w1.weather.gov/glossary/

Warning – A warning is issued when a hazardous weather or hydrologic event is occurring, is imminent, or has a very high probability of occurring. A warning is used for conditions posing a threat to life or property.

Table 5-3: Summary of NWS Alert Durations by Type

Alert Type	Phenomena	Pre-deployment Period Alert-hours (in 8.5 months)	Post-deployment Period Alert-hours (in 3.5 months)
Watch	Areal Flood	122.0	0.0
	Flash Flood	1.5	0.0
	Severe Thunderstorm	1.0	8.5
	Tornado	29.9	1.4
	Winter Storm	0.5	0.0
Advisory	Brisk Wind	5.8	0.0
	Dense Fog	99.2	54.5
	Flood	829.4	213.1
	Frost	0.0	9.1
	Lake-effect Snow	259.6	8.3
	Lakeshore Flood	13.3	0.0
	Wind Chill	571.2	316.7
	Wind	146.0	51.6
	Winter Weather	1,593.7	309.1
	Freezing Fog	8.5	0.0
	Freezing Rain	50.5	2.40
Warning	Areal Flood	160.8	0.0
	Blizzard	11.9	6.1
	Flash Flood	2.0	0.0
	Flood	984.2	55.0
	Freeze	0.0	28.8
	High Wind	57.8	0.0
	Ice Storm	15.5	0.0
	Lake-effect Snow	68.8	0.0
	Severe Thunderstorm	7.7	0.5
	Tornado	1.0	0.2
	Wind Chill	386.4	84.3
	Winter Storm	431.0	118.2

Source: Battelle, data from MDOT

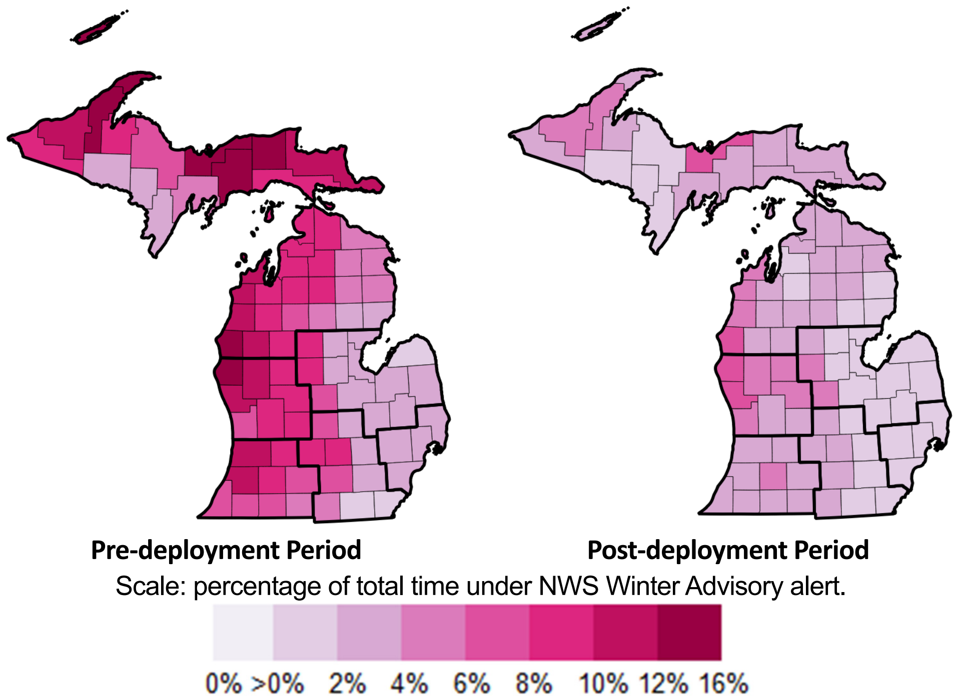
The values in Table 5-3 indicate that the total hours of alerts related to winter weather are the most prominent types of alerts that were issued during the pre-deployment and post-deployment evaluation periods. Because it is of interest to analyze the effects of the system when a storm is occurring, only advisory and warning data are used, as these alerts pertain to imminent or ongoing weather events.

The analysis focuses on winter-weather-related NWS Advisories and Warnings for storms that are assumed to have had a direct adverse impact on the driving conditions, including the following types:

NWS Winter Advisory: Lake-effect Snow, Winter Weather, Freezing Fog, Freezing Rain

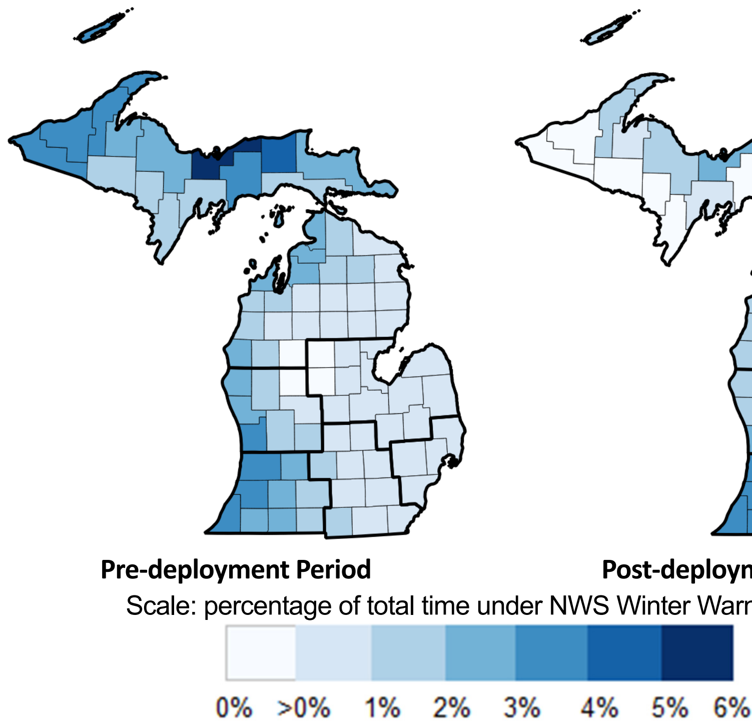
NWS Winter Warning: Blizzard, Ice Storm, Lake-effect Snow, Winter Storm

Figure 5-4 and Figure 5-5 show the percentage of time each county is under an advisory or warning, respectively, for the pre-deployment and post-deployment evaluation periods. As the images show, the intensity of weather warnings varies throughout the state and from before implementation to after implementation. Thus, it is important to control for this variability when performing analyses.



Source: Battelle, data from MDOT

Figure 5-4: Percentage of Total Time under NWS Winter Advisories



Source: Battelle, data from MDOT

Figure 5-5: Percentage of Total Time under NWS Winter Warnings

5.2.5 Incident Log

The incident log data includes the date and time information for incidents that occurred during the pre-deployment and post-deployment evaluation periods. Several other crash report attributes are also included such as the roadway name, direction, cross-street, mile marker, region, county, weather, roadway condition, and incident description. Most importantly, incident information includes information regarding the county in which the incident occurred. Although information regarding the weather and/or road conditions can sometimes be found in the accident description, the time of the incident and the county where it took place are linked to the NWS Advisories and Warnings alert data to determine if the incident occurred during winter weather conditions.

The total number of incidents, the number of incidents that occurred during an NWS Advisory or Warning alert, and the percentage of all incidents that occurred during an NWS Advisory or Warning alert are listed in Table 5-4. As the table shows, incident distribution is uneven across regions, and therefore needs to be controlled in the analysis. Also the systemic decrease in the percentage of incidents that occurred during an alert provides further evidence that winter weather conditions were not as severe during the post-deployment period compared to the pre-deployment period. In the data analysis the incident data are presented to control for storm duration between the evaluation periods.

Table 5-4: Incident Data Overview

Region	Pre-deployment Period (8.5 months)			Post-deployment Period (3.5 months)		
	Total incidents	Occurred during alert	Percentage of incidents during alert	Total incidents	Occurred during alert	Percentage of incidents during alert
Bay	284	26	9%	87	3	3%
Grand*	873	-	-	251	-	-
Metro	3,493	210	6%	2,490	131	5%
North	48	15	31%	17	3	18%
Southwest	428	148	35%	137	33	24%
Superior	19	7	37%	10	4	40%
University	621	71	11%	217	12	6%

* Incident data was not able to be geo-located with alerts for Grand region.

Source: Battelle, data from MDOT

5.2.6 User Delay Cost (UDC) Data

The MDOT uses the measure of UDC for estimating the impacts of non-recurring congestion. For this particular project, the UDC was evaluated every hour during the pre-deployment and post-deployment evaluation periods for all highways in each county in Michigan. The UDC is a function of the value of time and the average speed of traffic on a given highway. As of 2013, the MDOT value of time assigned to passenger and commercial vehicles is $17.44 and $30.77 per hour, respectively. When average speed values fall below 60 mph on a particular highway, that highway will incur a UDC. The further below 60 mph the average speed is, the larger the magnitude of the UDC.

The UDC dataset does not provide any indication as to the reason for the UDC. However, because the data is county-based, it can be compared against the NWS Advisory and Warning alert data to estimate when UDC can be attributed to weather. A summary of weather-related UDC is in Table 5-5.

Table 5-5: Weather-Related UDC Summary

Region	Pre-deployment Period (8.5 months)			Post-deployment Period (3.5 months)		
	Total UDC	UDC during alerts	Percentage of UDC during alerts	Total UDC	UDC during alerts	Percentage of UDC during alerts
Bay	$16,747,500	$3,922,753	23%	$2,165,857	$271,869	13%
Grand	$38,675,733	$17,888,225	46%	$6,207,889	$1,232,126	20%
Metro	$358,754,542	$56,203,075	16%	$79,194,699	$5,837,433	7%
North	$2,118,542	$589,993	28%	$246,386	$37,240	15%
Southwest	$33,987,444	$18,649,875	55%	$5,762,046	$3,051,638	53%
Superior	$246,618	$59,725	24%	$42,480	$3,316	8%
University	$53,226,000	$12,589,380	24%	$10,445,792	$1,453,157	14%

Source: Battelle, data from MDOT

5.3 Data Analysis

5.3.1 Hypothesis 1: The system will improve the real-time traffic management capabilities of MDOT TOC Operations staff during weather events

The objective for Hypothesis 1 is to assess whether or not the Wx-TINFO system improves the real-time traffic management capabilities of MDOT TOC staff during weather events. The evaluation plan includes three MOEs for testing this hypothesis:

1. Increased number of reported significant weather events
2. Decreased response time to post and update travel impacts due to weather events
3. Improved perception of value by TOC Operators

5.3.1.1 Measures of Effectiveness

MOE 1: Increased number of reported significant weather events.
The first MOE involves determining whether more weather events are reported to the public. Currently, the only way MDOT communicates weather information is through messages posted on DMSs. Thus, a reported weather event is defined as posting a weather-related message to a DMS. These messages are either viewed by drivers as they travel by the DMS or by a user selecting a DMS icon from the Mi Drive website.

To assess whether there is an increased number of reported significant weather events, a before-and-after analysis is conducted. As shown in Table 5-6, the absolute volume of weather-related messages from the pre-deployment evaluation period is greater than the post-deployment evaluation period. However, there are several other factors that need to be accounted for to understand the magnitude of the increase in weather-related information. Two main factors for this include the longer duration of the pre-deployment evaluation period (8.5 months versus 3.5 months) and the differences in winter weather (greater total storm duration in the pre-deployment).

Table 5-6: Number and Duration of Weather-Related Messages by Region

Region	Pre-deployment Period (8.5 months)		Post-deployment Period (3.5 months)	
	Total number of messages	Total message duration (days)	Total number of messages	Total message duration (days)
Bay	4,021	109	3,158	29
Grand	35,855	508	11,330	156
Metro	8,231	3,811	1,337	369
North	154	65	3,404	108
Southwest	37,813	265	24,832	124
Superior	360	221	245	36
University	17,389	301	16,079	88

Source: Battelle, data from MDOT

To control for these two factors the analysis takes into account the duration each message was shown. For a given weather event, a message that is shown for one hour should not be given the same weight as a message that is shown for a longer duration, such as three hours. Thus, instead of assessing the number of messages, the total duration of weather-related messages during weather events is assessed, as shown in Table 5-7.

One might expect the duration of weather-related messages to increase as the duration of winter weather increases, all else being equal. Normalizing the duration of weather-related messages by the duration of the weather event is an effective means of controlling for differences in weather severity between the pre-deployment and post-deployment evaluation periods. To capture the occurrence and duration of winter storms the duration of winter weather-related NWS Advisories and Warnings in the evaluation periods is recorded. A given NWS alert has an issue and expiration time, and is provided at the county level. The duration of alerts for a given region equals the sum of the duration of all NWS Advisories and Warnings for all counties in the region. Only counties that contain DMS infrastructure are included in calculating the regional alerts duration. The duration of winter weather-related DMS messages during active NWS Advisories and Warnings is calculated using the posting and expiration time (or time replaced) of messages. The total duration of weather-related messages for a given region equals the sum of the duration of weather-related messages in the region during the NWS Advisories and Warnings affecting the DMS displaying the message.

A test statistic is devised by taking the total duration of weather-related messaged during NWS Advisories and Warnings and dividing by the total duration of NWS Advisories and Warnings. The resulting number represents the average number of DMSs displaying weather-related messages during weather conditions that are severe enough to produce an NWS alert. While the resulting value controls for weather severity, it does not control for the number of DMSs in each county/region. Thus, the output cannot be compared between regions, but the same region is compared during the pre-deployment and post-deployment evaluation periods. The total message duration, total alert duration, average number of DMS with weather-related messages during storms, and percent change from the pre-deployment to post-deployment evaluation periods are listed in Table 5-7.

Table 5-7: Regional Weather-Related Messages during Storms

Region	Pre-deployment Period (8.5 months)			Post-deployment Period (3.5 months)			Change
	Storm message duration (days)	Alert duration (days)	Average number DMS with message in alert	Storm message duration (days)	Alert duration (days)	Average Number DMS with message in alert	Percent change pre- to post-deploy.
Bay	33	58	0.57	14	10	1.36	139%
Grand	242	96	2.52	56	21	2.63	4%
Metro	349	26	13.42	12	6	2.01	-85%
North	32	22	1.45	5	2	2.15	48%
Southwest	145	154	0.94	97	34	2.86	204%
Superior	84	129	0.65	23	19	1.22	87%
University	88	68	1.29	48	15	3.19	147%

Source: Battelle, data from MDOT

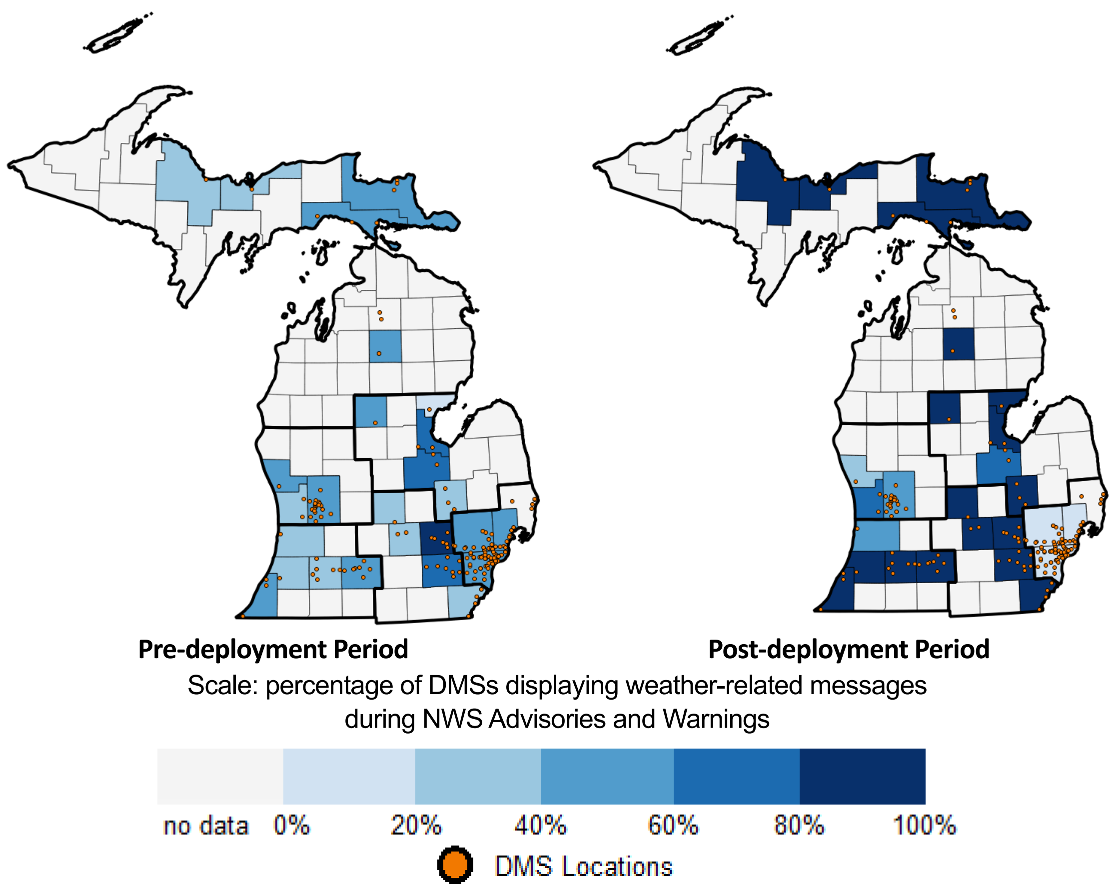
All regions except Metro show an increase in the average number of DMSs displaying weather-related information during NWS Advisories and Warnings when comparing between the pre-deployment evaluation period and the post-deployment evaluation period. The county-level map is in accordance with this finding, as most counties show an increase in weather-related messaging (represented by darker shades of blue). This is a positive indication that changes in operations between the pre-deployment and post-deployment evaluation periods have resulted in increased messaging to travelers. However, the Metro region shows a stark decline in DMSs displaying weather-related information during NWS Advisories and Warnings, which is consistent with the large decline in the duration of weather-related messages in the Metro region.

Another test statistic is devised by taking the number DMS displaying winter weather-related messages during NWS Advisories and Warnings and dividing by the total number of DMS available. The resulting number represents the percentage of DMSs displaying weather-related messages during weather conditions that are severe enough to produce an NWS alert. The resulting value controls for weather severity and for the number of DMSs in each county/region. Thus, the output can be compared between regions and during the pre-deployment and post-deployment evaluation periods. The calculated values are listed in Table 5-8. A detailed county-by-county map of the percentage of DMSs displaying weather-related information is shown in Figure 5-6.

All regions except Metro show an increase in the percentage of DMSs displaying weather-related information during NWS Advisories and Warnings when comparing between the pre-deployment evaluation period and the post-deployment evaluation period. The county-level map is in accordance with this finding, as most counties show an increase in the percentage of DMSs displaying weather-related messages during NWS Advisories and Warnings (represented by darker shades of blue). This is another positive indication that changes in operations between the pre-deployment and post-deployment evaluation periods have resulted in increased messaging to travelers. However, the Metro region shows a significant decline. This is consistent with the earlier analysis and the decline in the duration of weather-related messages in the Metro region.

Table 5-8: DMSs Displaying Weather-related Messages during NWS Advisories and Warnings

Region	Pre-deployment Period DMS available during NWS alerts			Post-deployment Period DMS available during NWS alerts			Change
	Number displaying weather messages	Total number available	Percent displaying weather messages	Number displaying weather messages	Total number available	Percent displaying weather messages	Percent pre- to post-deploy.
Bay	81	163	50%	24	28	86%	72%
Grand	302	744	41%	106	189	56%	38%
Metro	670	1181	57%	27	255	11%	-81%
North	52	93	56%	17	18	94%	69%
Southwest	202	495	41%	139	145	96%	135%
Superior	111	264	42%	44	50	88%	109%
University	218	345	63%	77	80	96%	52%



Source: Battelle, data from MDOT

Figure 5-6: DMSs Displaying Weather-related Messages during NWS Advisories and Warnings

MOE 2: Decreased response time to post and update travel impacts due to weather events. Significant weather events are typically accompanied by one or more NWS alerts that intend to convey information to the public regarding future, impending, or prevailing weather conditions. Assuming that the objective of all weather-related messages is to provide travel impact information, then both the archived NWS alert data and DMS message data is used in a year-to-year before-and-after analysis. The spatial attribute of the NWS alert dataset is used to determine which DMSs should be impacted by the weather event that triggered the NWS alert. Furthermore, information regarding the time each NWS alert was issued and the time when a message is posted to a DMS has been obtained. Thus, for each NWS Advisory and Warning, it is of interest to see if a weather-related message is posted to a corresponding DMS. If so, the amount of time between the issuance of the NWS alert and the DMS message post is determined and recorded. This data is divided into the pre-deployment and post-deployment evaluation periods to assess the percentage of time DMSs display information related to an NWS Advisory or Warning and to assess changes in the response time.

In order to estimate the amount of time it takes to respond to a weather event by posting and updating DMS messages, it is important to first assess the number of DMSs affected by storms that should display a storm-related message. As discussed in previous sections, NWS warnings and advisories contain information regarding the onset and conclusion of various storm conditions for impacted counties. The NWS Advisory and Warning alert data is used to determine which DMS devices should be used to convey weather-related information associated with the given storm.

Response time cannot be directly measured because the exact specific input that led to a DMS message being generated cannot be precisely discerned in all instances—especially in the pre-deployment period. Therefore, a proxy measure of advance notification time is formulated to assess whether messages are being posted further in advance of winter weather conditions (based on NWS Advisories and Warnings).

For the analysis, DMSs displaying a weather-related message anytime from three hours prior to issuing an NWS Advisory or Warning up until the expiration time are selected to represent the number of DMSs displaying weather-related information during winter weather. The number of DMSs displaying weather-related information divided by the number of DMSs affected by a storm gives the percentage of DMSs displaying weather-related information during storms that produce NWS Advisories and Warnings. This gives an indication how much storm-related information is posted.

Next, for DMSs that display information relating to a storm, the advance notification time is assessed. Using the NWS alerts to define when a weather event starts in a particular area (with DMSs), the difference between the posting time of a storm-related message and the start time of the storm is used to measure advance notification time. A before-and-after comparison of this value gives an indication whether or not the system has improved the timeliness of information related to weather events.

As with the previous analysis, the counties are aggregated into regions. Table 5-9 provides the total number of DMSs that were impacted by storms, the percentage of DMSs that display weather-related information during an alert, and the average advance notification time for those weather-related messages. The number of DMSs impacted by storm-alerts is greater than the number of DMSs in a particular region because each DMS is affected by multiple alerts.

Table 5-9 illustrates that most regions show a significant increase in the percentage of DMS that display weather-related information during alerts. Most regions increase from 40–60 percent to 85–95 percent. The exception is the Metro region showing a large decline—likely due to the decrease in weather-related messaging. For the DMSs that display weather-related information, the average advance notification time shows only a slight improvement—closer to the chosen maximum three-hour period prior to the alert. Given the increase in the percentage of DMS displaying weather-related messages during alerts, the consistency of this value indicates that messages continue to be posted in a timely manner. This message timeliness in the post-deployment period was in spite of the survey results indicating that operators were still getting accustomed to the new multi-step message approval process (the survey questions are examined later in the discussion on MOE 3).

Table 5-9: Regional Message Posting Rates and Response Times

Region	Pre-deployment Period			Post-deployment Period			Change
	Storm-impacted DMS	Percent of DMS with Wx message in alert	Average advance notice* (3 hours max.)	Storm-impacted DMS	Percent of DMS with Wx message in alert	Average advance notice* (3 hours max.)	Percent change pre- to post-deploy.
Bay	163	50%	2.77	28	86%	2.86	3.2%
Grand	744	41%	2.71	189	56%	2.67	-1.5%
Metro	1,181	57%	2.82	255	11%	2.94	4.3%
North	93	56%	2.84	18	95%	2.86	0.7%
Southwest	495	40%	2.74	145	96%	2.87	4.7%
Superior	264	42%	2.81	50	88%	2.88	2.5%
University	345	63%	2.79	80	96%	2.88	3.2%

* The average advance notice is the average time that the weather-related message is active before the NWS advisory or warning is active (i.e., before the storm hits). Messages active more than 3 hours before the storm are capped at a maximum of 3 hours. A larger average advance notice value indicates that the weather related messages are being posted earlier—that is, giving travelers earlier notification.

Source: Battelle, data from MDOT

Figure 5-7 shows the change from the pre-deployment to the post-deployment evaluation period in message posting time in response to impending winter weather based upon NWS Advisories and Warnings. As previously noted, there is a large Increase in the percentage of DMS displaying weather-related messages during alerts—except in the Metro region. (Denoted by the decrease in the brown bars in the figure.) The additional information on percentages of when weather-related messages are posted shows only that the division between the time blocks appears to be proportionally consistent.

Source: Battelle, data from MDOT

Figure 5-7: Percentage of DMS displaying Weather-Related Messages in Advance of NWS Advisories and Warnings

MOE 3: Improved Perception of Value by TOC Operations Staff.
To assess MOE 3 in this study, a survey of TOC Operators was conducted. The survey was given to 11 MDOT traffic management professionals in May 2015 after the end of the post-deployment evaluation period. The survey was designed to evaluate the perception of the value of the project. Respondents were asked questions regarding how the Wx-TINFO system improved traffic management. As previously explained, it is important to note that the Wx-TINFO system function of

sending DUAP weather alerts to the ATMS for possible DMS message posting was not live until January 15, 2015. As such, the operators' exposure to the system was limited. One operator indicated that this limited their ability to provide good insight. Furthermore, adjustments have been made to the Wx-TINFO system since the survey to address some operators' concerns. Survey questions along with a summary of the responses are listed below.

Question 1 – Using the new system, are you able to provide more road weather information to travelers?
Five out of the eleven operators said that Wx-TINFO was able to provide *more* (and precise, for some) road weather information, more so for areas that are not visible (via camera). However, one mentioned that this information is not always useful to ascertain road conditions and one questioned the accuracy of the information being provided.

One operator felt that Wx-TINFO is equally as effective as the previous method and reiterated the problem with the accuracy of ATMS.

Three operators felt that the new system rarely enabled them to provide more road weather information except in areas with no camera coverage, but one noted that even this information could not be used until verified. For example, WX-TINFO starts messaging for events well before the weather events are forecasted to begin (according to NWS).

One operator felt that the system was not only unhelpful in providing more information, but also questioned the accuracy *and* amount of resources needed to work the system due to added weather input streams and the need to determine which inputs to act on, or override. This operator noted inconsistent results, which were later addressed in a system update.

Question 2 – Is this new road weather information more specific and more valuable to travelers than the information provided before?
Three out of the eleven operators agreed that Wx-TINFO is more specific about weather in specific areas and that DMS is changed to relay information about weather events in those specific locations. One operator noted that this can only be the case if the data are accurate.

Seven operators' responses seemed indifferent or unhappy with the new system. Two noted that the system does give more information, but it is not always useful for road conditions application. For instance, one mentioned that the low visibility is helpful, and having watches and warning feed to ATMS is useful. However, heavy rain messages are not. The other three noted the following issues with the new system at that point in time:

- Weather information is less detailed than NWS (location info)
- Road weather condition information is more detailed/automatic—too many alerts for weather events lasting only 10–20 minutes
- Questionable accuracy of data
- Wasted time verifying 'hundreds of weather events' and posting to DMS

Note: as described previously, the information from the operator surveys was used along with other information to make system improvements to address these concerns after the post-deployment evaluation analysis period.

Question 3 – Has the time required for you to implement or update traffic management strategies and information (on DMS or Mi Drive) increased, decreased or remained the same? Generally, the responses to this question were negative. Only one operator responded that time had decreased stating that pre-chosen DMS messaging processed more quickly. Another operator stated that the time remained the same, but mentioned that Wx-TINFO is still in testing and that usage is limited. Wx-TINFO was newly deployed at the time of the survey and the continuing feedback was used to refine the system.

The remaining operators responded that the system has increased the time due to the following reasons:

- ATMS performance issues
- Too many alerts to weather events increases time spent monitoring weather
- Verifying weather events—increased time and resources (two people needed to verify)
- Before only had to react to email messages and decide whether or not to implement. Now have to validate information on ATMS, decide whether or not to message, acknowledge, confirm and/or terminate the event in ATMS, add or delete DMS and portable DMS, and change suggested template to appropriate message.
- Even after verifying, still have to type in the “qualifier” information (e.g., counties affected, “ahead”, “starting at 9pm”)

In the previous MOE 2 discussion, the results indicate that messages continued to be delivered in a timely manner, even with the operators’ initial challenges with the new message posting process. Here again, improvements to the system were made shortly after the survey was conducted.

Question 4 – Overall, please explain how the new system has affected your job at the TOC. What additional changes are needed to help improve your functions and daily operations? All but one of the eleven operators felt that the system resulted in wasted time due to the excessive number of weather alerts, many of which are not applicable to the road weather conditions, or make it difficult to discern whether or not something is truly affecting traffic. This, coupled with trying to monitor traffic and incidents, makes the job more difficult. Specific changes and improvements mentioned include:

- Add function so DMS auto-populates with the correct message and can be removed whenever weather changes
- Reduce [alerts for non-severe versions of] weather events like rain, wind, and fog since MDOT does not post for those kinds of weather events
- System should not require operator to verify weather events
- System should be designed to reduce work for operators
- Too many icons for weather events that are closely related
- Provide location information or at least details from NWS messages in Notes section
- Messaging matrix should more closely match how operators actually message for events with less confusion on ATMS priority versus event impact level
- Add some event types to clarify if “snow covered roads” are actually snow covered or just slippery due to snowing in that area

Many of these improvements to the system were made after the post-deployment evaluation period shortly after the survey was conducted.

Question 5 – Overall, do you think the agency is better off with the new system than without it? Six of the eleven operators had a favorable opinion of the system. One operator completely agreed that the agency is better off with the new system, particularly because of the quicker alerts of expected weather conditions. Two others felt that the agency is better off with the new system, but that some issues need to be fixed in order to optimize the system. Three felt that the system could be useful if it was refined, but many issues need to be addressed first. Five operators felt that the agency was not better off with the new system.

5.3.1.2 Hypothesis 1 Summary and Conclusions

The purpose of the MOEs is to assess the impact the system has on the traffic management capabilities of MDOT TOC Operations staff during weather events. The Hypothesis 1 MOEs assessment provided sufficient evidence for supporting Hypothesis 1. A summary of the three assessments associated with Hypothesis 1 are as follows:

- For six out of seven maintenance regions there was an increase in the average number of DMSs that display weather-related information during NWS Advisories and Warnings, and an increase in the percentage of DMSs that display weather-related information at some point during NWS Advisories and Warnings
- For DMSs that display weather-related messages during and up to three hours before NWS advisories and warnings, the advance notification time remains about the same if not slightly earlier for six out of seven maintenance regions
- Overall, about half of operators have a favorable impression of the system. While it was noted that getting the information in advance was helpful, there were system issues at the time that needed to be addressed. For instance, there are many Wx-TINFO alerts generated that do not require a message to be posted, and verifying weather events can be a time-consuming process. Improvements were made to the system shortly after the evaluation period to address these issues.

Implementing the system appears to have increased the number of decisions made by TOC Operations staff. However, the overall result is that more messages are being posted to DMSs during inclement winter weather. That is, more weather-related information is being made available to drivers through messages on DMS and to internet users through the Mi Drive website during inclement winter weather conditions. This fact showcases the increased management capabilities of TOC Operations staff using the system.

The TOC Operations staff seemed to perceive value of the system in terms of its efficiency. Survey results (along with further dialogue with TOC Operations staff) can help to streamline the system output to reduce the strain on staff, improve their perception of the system, and provide further support for system implementation. These system adjustments began immediately after the deployment and survey, and continued through the evaluation analysis period. Automating some of the decision-making steps the TOC staff has to undertake with the new system will improve their efficiency.

5.3.2 Hypothesis 2: The system will improve the timeliness and content of road weather condition reporting updates to the traveling public

MDOT provided the traveling public with more weather-related alerts (measured as messages during NWS Advisory or Warning alert hours) in the Wx-TINFO project post-deployment evaluation period. The system allows weather data to be collected and processed in real-time, and provides recommended messages for posting to DMSs and the Mi Drive website. Increased capability of the system is expected to provide motorists with more valuable, accurate, and timely weather-related information, which will enable them to make safer and timelier travel decisions, both pre-trip and en-route. Ideally, the timeliness and content of road weather condition messages would improve after implementing the system. The five MOEs for this hypothesis, listed below, are evaluated in the following subsections.

1. Decrease the time it takes for travelers to receive weather-related information, which subsequently improves (decreases) the time for them to respond to weather impacts
2. Improved traveler perception and value of road weather information
3. Increased specificity of road weather information
4. Reduced incidents and crashes due to weather
5. Decreased weather-related travel delays

5.3.2.1 Measures of Effectiveness

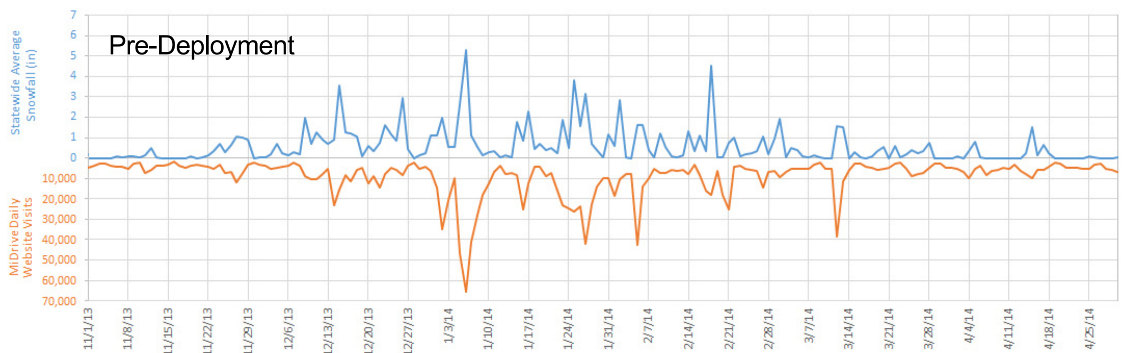
MOE 1: Decrease the time it takes for travelers to receive and respond to travel impacts due to weather events

The goal of this MOE is to determine if the system decreases the amount of time it takes for travelers to receive and respond to a weather-related message. The analysis in the previous hypothesis shows that in most regions the average number of DMSs posting winter-weather alert messages increased and those messages were posted slightly earlier with the new system in place compared to the pre-deployment period. These are good indicators of improved coverage and message timeliness for travelers. It is not enough to assume that travelers will instantly receive and act upon information posted through a DMS. Data specific to directly assessing the amount of time it takes travelers to receive and respond to the messages is not available. This would require techniques such as driver surveys and/or probe vehicles, which time and budget did not allow. The DMS messages accessed through the Mi Drive website could be used, but as described previously, this data is only available on a day-by-day basis for each DMS, thus eliminating the possibility of using granular Mi Drive DMS selections to assess the amount of time it takes for the public to receive DMS messages.

However, there is an alternative measure that may lend insight into assessing this MOE. Rather than assessing the time it takes for a traveler to select a DMS from Mi Drive, the absolute number of DMSs selected is assessed. This provides an indication as to the number of travelers receiving information posted to DMSs. Since Mi Drive DMS selection data is only available on a daily basis, there is no method of assessing whether or not the DMSs selected were displaying weather-related messages.

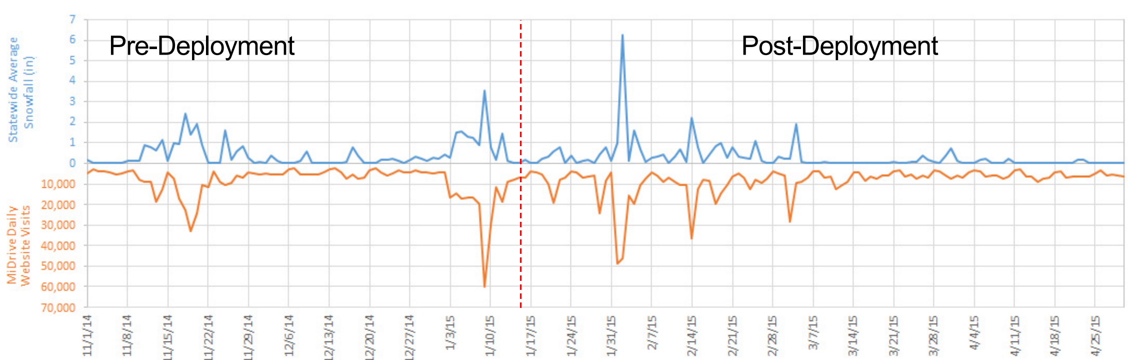
From the analysis of the Mi Drive usage data, there is a clear correlation between the amount of snowfall and the number of website visits. This trend is shown in Figure 5-8 and Figure 5-9. This may also influence the number of DMSs selected from the website. Snowfall data is used to estimate the occurrence of storm days during which DMS selections and website visits is evaluated. Each region contains several National Oceanic and Atmospheric Administration weather stations for which daily snowfall data was obtained. The regional snowfall average is calculated by averaging all weather station daily snowfall observations. Only days where regional average snowfall is greater than one inch are assessed—this removes bias caused by DMS selections on days when winter weather is not as intense. The number of DMSs selected from the Mi Drive website and the number of DMSs selected per inch of snow by region for the pre-deployment and post-deployment evaluation periods are displayed in Table 5-10. The total website visits are evaluated in Table 5-11.

The results for each region appear to be mixed. While daily DMS selections increased for the North, Southwest, and Superior regions, they decreased in the Grand region, and remained relatively constant for the Bay, Metro, and University regions. The DMS selections per inch of snow show a relatively similar trend. Overall Mi Drive website visits appear to have increased from the pre-deployment to the post-deployment evaluation period. A roughly 25 percent increase in Mi Drive website visits is noted when statewide average snowfall exceeds one inch, while Mi Drive website visits per inch of snow increased by about 20 percent.



Source: Battelle, data from MDOT

Figure 5-8: Winter of 2013–2014 Mi Drive Visits and Statewide Snowfall Time Series



Source: Battelle, data from MDOT

Figure 5-9: Winter of 2014–2015 Mi Drive Visits and Statewide Snowfall Time Series

The results of the Mi Drive DMS Selections by Region are mixed, with some regions increasing and some decreasing. Because the location of the person selecting the DMS cannot be determined from the website data (i.e., the person may not be in the region with the site) the analysis cannot provide conclusions regionally of how people are responding to the new information being provide by Wx-TINFO through Mi Drive.

Table 5-10: Mi Drive DMS Selections by Region

Region	Pre-deployment Period		Post-deployment Period		Change
Location of DMS selected	DMS selections per weather-day*	DMS selections per inch of snow*	DMS selections per weather-day*	DMS selections per inch of snow*	Percent change per inch of snow pre- to post-deploy.
Bay	24.8	11.1	21.7	8.1	-27%
Grand	61.9	25.2	38.4	16.1	-36%
Metro	119.9	44.4	111.8	31.6	-29%
North	2.9	1.3	7.75	4.4	238%
Southwest	105.3	37.3	177	59.3	59%
Superior	21.0	9.6	27	15.5	61%
University	109.2	39.7	108.2	39.4	-1%

* 'Weather-day' is defined as a day with at least one inch of snow, on average for the region.

Source: Battelle, data from MDOT

The analysis of the Mi Drive website visits shows that more people are visiting the website on storm weather days from the pre-deployment period to the post-deployment period.

Table 5-11: Mi Drive Website Visits

Pre-deployment Period		Post-deployment Period	
Website visits per weather-day*	Website visits per inch of snow*	Website visits per weather-day*	Website visits per inch of snow*
19,011	10,168	26,162	12,122

* 'Weather-Day' is defined as a day with at least one inch of snow, on average statewide.

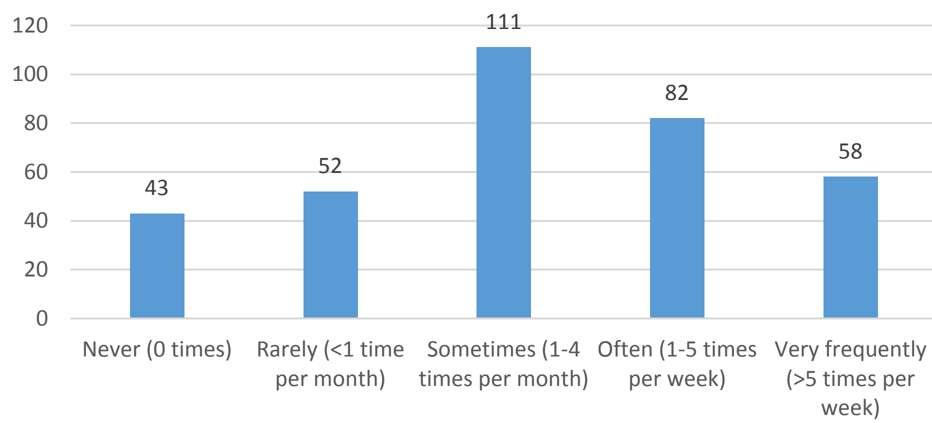
Source: Battelle, data from MDOT

MOE 2: Improved traveler perception and value of road weather information

Public perception is also important to successfully provisioning road weather information. To address this MOE, a survey was developed to evaluate traveler's perceptions of the effectiveness of the new road weather information provided by MDOT during inclement weather conditions. The survey, developed and administered through SurveyMonkey, was accessible through a link on the Mi Drive website. Survey data is used to assess the public's knowledge of weather information on the Mi Drive website and DMSs, and how information conveyed through these means may have changed travel patterns/habits. A copy of the traveler survey is provided in Appendix C.

From the Mi Drive website, users can obtain information regarding construction, traffic cameras, roadway speed (where available), incidents, DMSs, truck parking, carpool lots, rest areas, roadside parks, and passenger/public airports. The sixteen-question survey was posted on the Mi Drive website between 3/30/2015 and 5/15/2015 (these dates are after Wx-TINFO system implementation). A total of 346 responses were received, and 280 respondents completed all questions on the survey. These responses are used to indicate the degree to which travelers have an increased awareness of road weather information. The summary in Figure 5-10 describes the responses given by respondents, and provides an indication of the effectiveness of road weather information on roadways in Michigan. It is important to note that survey participation was completely voluntary, and no personally identifiable information was collected. Also, it is important to note that because the link to the survey was provided though the Mi Drive website, the answers provided may not accurately represent the attitudes and perceptions of all drivers.

How often do you use the Mi Drive website to get real-time traveler information before you make a trip? *This question was asked to everyone surveyed.*
Responses to this question indicate that users are most likely to access the Mi Drive website for real-time travel information between one and four times per month. Lower percentages of respondents indicate they accessed the Mi Drive website for real-time travel information more or less frequently. About 88 percent of respondents had accessed the site at one time or another for real-time travel information. About 70 percent access the website at least once per month, 40 percent access the website at least once per week, and 17 percent access the website on a nearly daily basis.

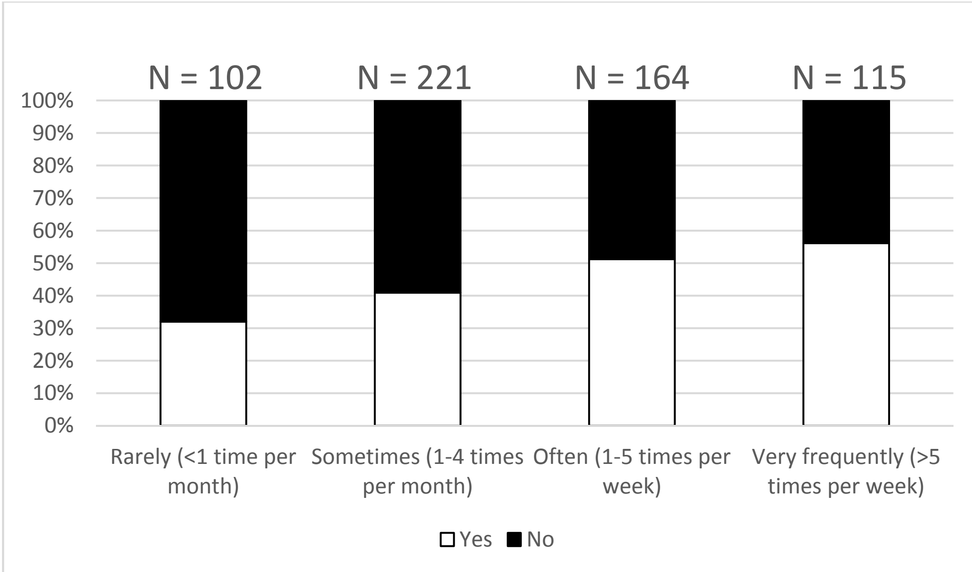


Source: Battelle

Figure 5-10: Mi Drive Survey Responses – Question 1 – Mi Drive Pre-Trip Usage

Do you use the weather information available on the Mi Drive website? *This question is only asked to respondents that selected rarely, sometimes, often, or very frequently as their answer to the previous question.*

Of the respondents that indicated they use the Mi Drive website for real-time travel information, about 46 percent of respondents overall use Mi Drive to get weather information (see Figure 5-11). Interestingly, as the frequency with which a respondent accesses the website increases, so does the likelihood they use the website to obtain weather information. Roughly one third of respondents that access Mi Drive less than once per month use the website to get weather information. For those who access Mi Drive 1 to 4 times per month, 40 percent access weather information. About half of respondents that access the Mi Drive website 1 to 5 times per week also access weather information, while about 57 percent of respondents that access Mi Drive more than 5 times per week use the website to access weather information.

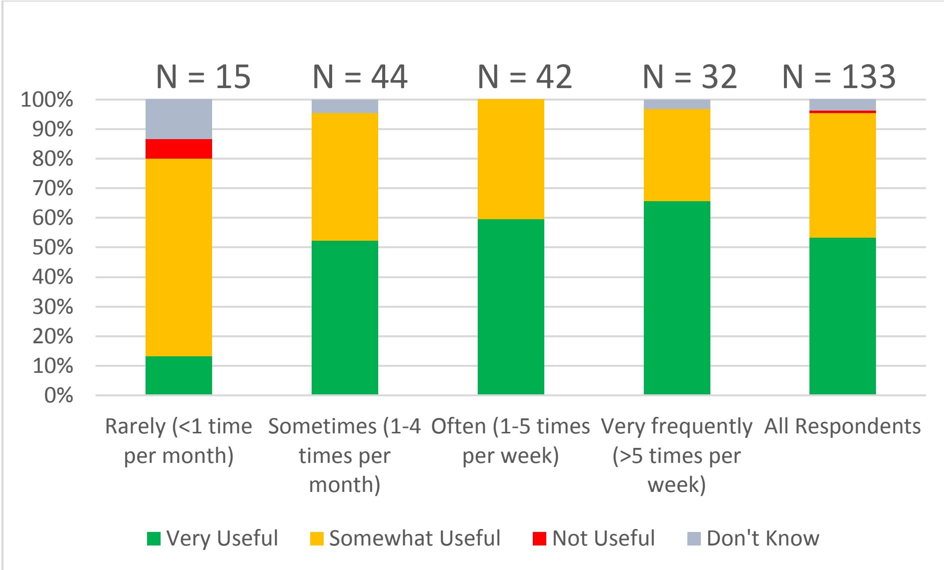


Source: Battelle

Figure 5-11: Mi Drive Survey Responses – Question 2 – Mi Drive Weather Information Usage

How useful to you is the weather information available on the Mi Drive website during bad weather conditions? *This question is only asked to respondents that selected rarely, sometimes, often, or very frequently as their answer to the first question, and selected yes as their answer to the second question.*

Of the respondents that use the Mi Drive website for real-time travel information and weather information, approximately 96 percent of respondents indicate the weather information presented on the Mi Drive website is useful during bad weather conditions (see Figure 5-12). Interestingly, as website visit frequency increases, so does the likelihood that the user finds weather information “very useful.”

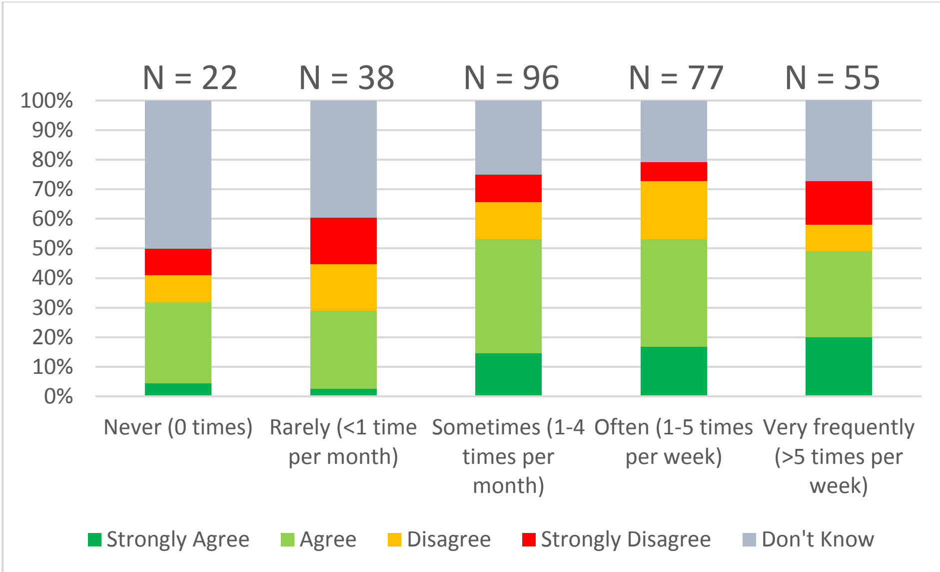


Source: Battelle

Figure 5-12: Mi Drive Survey Responses – Question 3 – Mi Drive Information Usefulness

Please indicate the degree to which the Mi Drive weather information has affected your trips during bad weather conditions ("I have changed the timing of one or more trips."). *This question was asked to everyone surveyed.*

Overall, about 47 percent of respondents either agree or strongly agree they have changed the timing on one or more trips after viewing Mi Drive. As shown in Figure 5-13, the trend between using Mi Drive to get real-time travel information and the degree to which Mi Drive weather information changed the timing of one or more trips is not as clear. Around 30 percent of respondents that either never or rarely access Mi Drive for real time travel information agree or strongly agree that weather information has made them change one or more trips. This fraction increases to slightly over 50 percent for respondents that access the Mi Drive website sometimes or often. Interestingly, the fraction decreases again for respondents that access the website very frequently. While this may seem somewhat counterintuitive, it is possible that persons who access travel information on a very frequent basis are more likely to downplay its significance, particularly in its ability to affect travel.

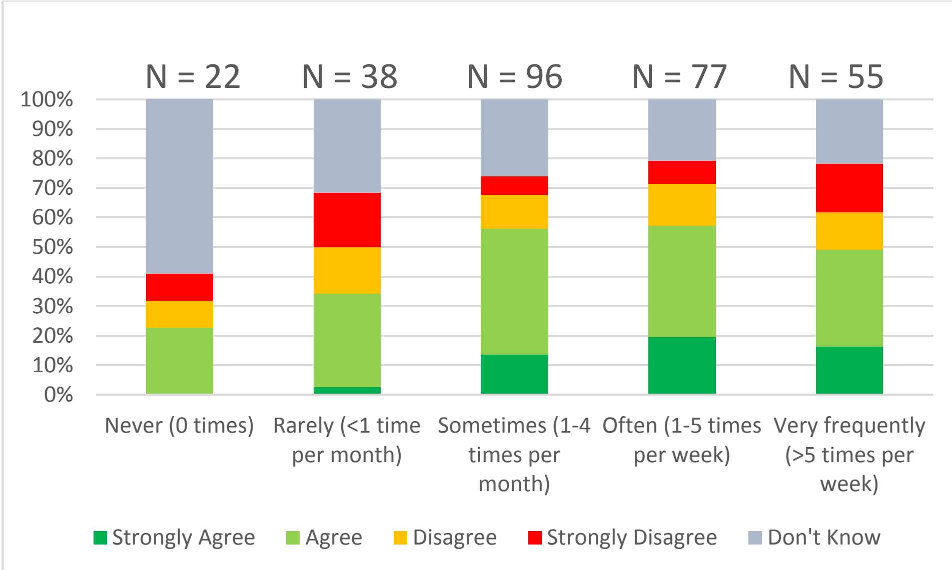


Source: Battelle

Figure 5-13: Mi Drive Survey Responses – Question 4a – "I have Changed the Timing of One or More Trips."

Please indicate the degree to which the Mi Drive weather information has affected your trips during bad weather conditions ("I have changed the routing of one or more trips."). *This question was asked to everyone surveyed.*

As a whole, 49 percent either agreed of strongly agreed they have changed the routing of one or more trips (see Figure 5-14). This is very similar to the percentage of drivers that have changed the timing of trips. A similar trend is noted for this survey question. There is increasing likelihood of agreeing with the statement as Mi Drive website access increases. However, the likelihood decreases for very frequent users.

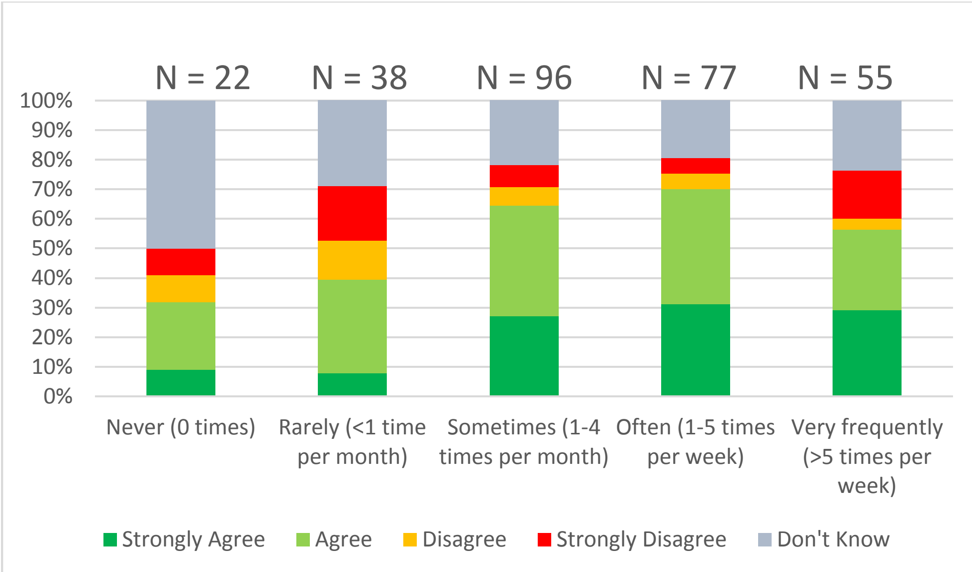


Source: Battelle

Figure 5-14: Mi Drive Survey Responses – Question 4b – "I have Changed the Routing of One or More Trips."

Please indicate the degree to which the Mi Drive weather information has affected your trips during bad weather conditions ("I have felt more prepared for one or more trips."). *This question was asked to everyone surveyed.*

Overall, 58 percent of respondents either agree or strongly agree they have felt more prepared for one or more trips (see Figure 5-15). This is a greater percentage compared to the percentage of responses that agree or strongly agree the weather information is effective in changing the route or timing of trips. This is an indication that weather information provided is slightly less likely to cause drivers to change the route or timing of their trip, and slightly more likely to prepare drivers for the road ahead. This may be especially true for mandatory trips when drivers bear a high burden for not taking a trip at a specific time. Unfortunately, current data does not allow this to be confirmed. Once again, the same trend from the previous two survey questions is noted. There is increasing likelihood of agreeing with this statement as Mi Drive website access increases. However, the likelihood decreases for very frequent users.



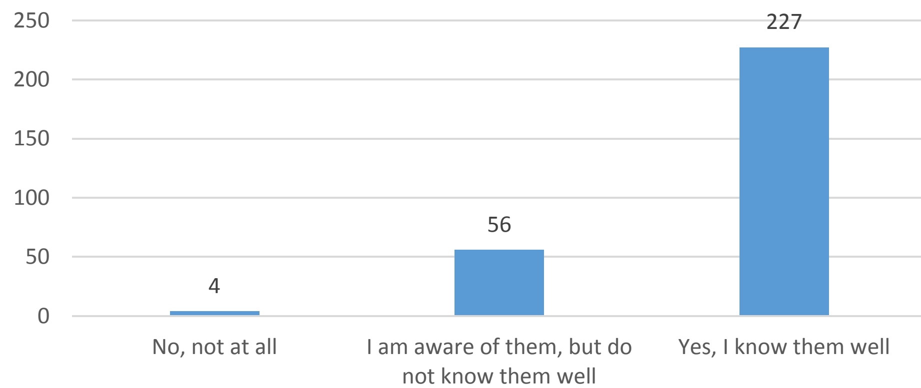
Source: Battelle

Figure 5-15: Mi Drive Survey Responses - Question 4c – "I have Felt Prepared for One or More Trips."

Please indicate the degree to which the Mi Drive weather information has affected your trips during bad weather conditions (other – comment box provided). *This question was asked to everyone surveyed. Providing comments was not required.*
Twenty-seven respondents provided comments in response to this question (see Figure 5-16). Common themes of comments include:

- Have never tried viewing Mi Drive weather information or did not know it was available (41 percent)
- New user or first time using web site (22 percent)
- Use other sources for obtaining weather information (7.4 percent)

Are you familiar with Michigan's Dynamic Message Signs (DMS), such as those pictured [in Appendix C]? *This question was asked to everyone surveyed.*
About 98.6 percent of respondents indicated they are aware of DMSs, while about 79 percent indicated they are both aware and know them well. Less than 2 percent of respondents say that they are not familiar at all with DMS messages in Michigan.

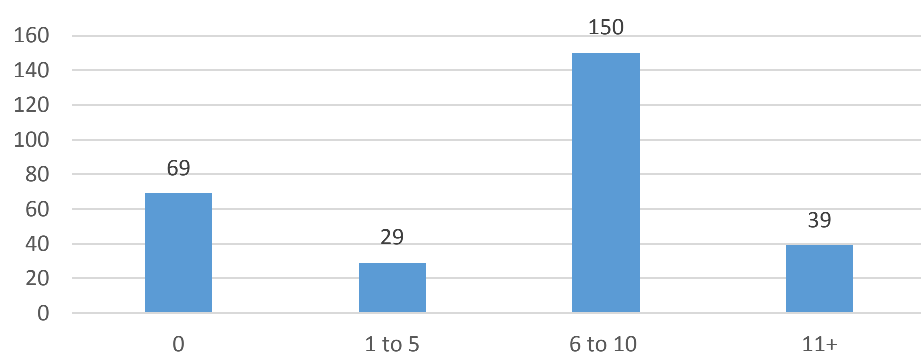


Source: Battelle

Figure 5-16: Mi Drive Survey Responses - Question 5 – DMS Awareness

How many weather-related DMS messages have you seen this year (2015)? *This question was asked to everyone surveyed. Note that the response to this question is time-dependent. Respondents who answered in the affirmative were likely to have seen a DMS in 2015 that was posted in the post-deployment evaluation period.*

About 76 percent of respondents indicated they have seen one or more DMSs with weather-related messages in the first four months of 2015 (see Figure 5-17). This is a relatively good indication that weather information is being communicated to many drivers using the roadway, even when considering about 24 percent of respondents have not seen a DMS with a weather-related message. The traveler awareness of these weather-related messages is high given low percentage of winter-weather related NWS alerts in the post-deployment period (which roughly coincided with the survey period). All counties had less than 10 percent of total time under NWS winter weather advisory (Figure 5-4) and less than five percent under NWS winter weather warning (Figure 5-5)—therefore the possibility of exposure to a weather-related message was relatively low. The awareness is still more impressive considering the counties with lower numbers of alerts had higher numbers of respondents (Figure 5-20). The locations of DMSs are displayed in Figure 5-3.



Source: Battelle

Figure 5-17: Mi Drive Survey Responses – Question 6 – Weather-Related DMS Messages Seen

If you have seen (or if you were to see) the following messages (shown in Figure 5-18) on a DMS as you were driving, did you (or would you) slow down and pay more attention to the roadway, or change your trip? *This question was asked to everyone surveyed.*

Messages about Snow Covered Roads and Slippery Roads have very similar response patterns, as shown in Figure 5-18. For these two messages, the most common reaction includes slowing down, but not changing trip plans. Between these two messages, about 85 percent of respondents indicated these messages would cause them to slow down, but less than 25 percent of all respondents would change their trip. The Blizzard Warning messages seems to have a greater impact, with more respondents selecting a response that indicates they would change their trip. For the Blizzard Warning messages, roughly 58 percent of respondents indicate they would change trip plans. This is over twice as many people who indicate that either of the other two messages would cause them to change their trip. About 65 percent of respondents also indicate this message would cause them to slow down. This is about 20 percent lower compared with each of the first two messages. It is possible that if drivers envision themselves driving in blizzard conditions they are already driving slowly, and that there would be no need to decrease speed further. Alternatively, if drivers envision seeing the Blizzard Warning message but do not actually observe blizzard conditions, they may continue at their current speed, waiting to decrease their speed until the condition warrants a decrease in speed.

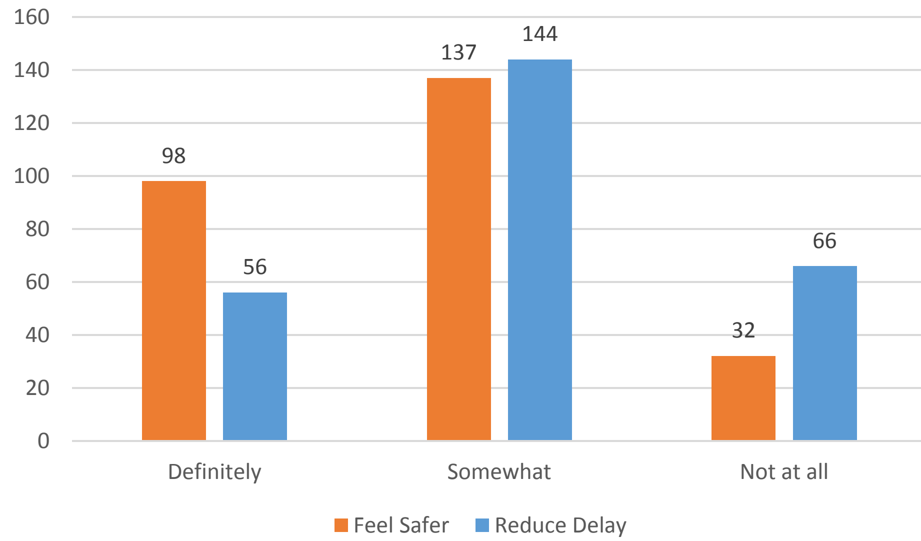
According to the survey, the Blizzard Warning message is likely to convince drivers to change their trip, whereas Snow Covered Roads and Slippery Roads messages are more likely to cause drivers to reduce speed.

SNOW COVERED ROADS ON I-96 AND I-94	**Saw DMS and…**	**Changed trip**	**Did not change trip**
	Slowed down	43 (16.0%)	180 (66.9%)
	Did not slow down	24 (8.9%)	22 (8.1%)
BLIZZARD WARNING	**Saw DMS and…**	**Changed trip**	**Did not change trip**
	Slowed down	89 (33.1%)	86 (32.0%)
	Did not slow down	66 (24.5%)	28 (10.4%)
SLIPPERY ROADS REDUCE SPEED	**Saw DMS and…**	**Changed trip**	**Did not change trip**
	Slowed down	39 (14.5%)	195 (72.5%)
	Did not slow down	14 (5.2%)	21 (7.8%)

Source: Battelle, data from MDOT

Figure 5-18: Mi Drive Survey Responses – Questions 7, 8, and 9 – DMS Message Response

Do these types of DMS messages about road conditions and weather information make you feel safer as you drive? Do you think these types of DMS messages about road conditions and weather information reduce travel delays? *Both questions were asked to everyone surveyed.* About 88 percent of respondents indicate that these DMS messages make them feel somewhat or definitely safer (see Figure 5-19). This is strong evidence that the information currently being provided to drivers has the ability to improve safety on roadways. However, there is slightly more skepticism regarding the effectiveness of DMS messages in reducing delay. Only 75 percent of respondents indicate that DMS messages either somewhat reduce or definitely reduce delay. However, this provides a relatively high degree of probability that information provided through DMS messages is helping to reduce travel delay.



This question was asked to everyone surveyed. Answering these questions was not required.

Source: Battelle, data from MDOT

Figure 5-19: Mi Drive Survey Responses – Questions 10 and 11 – Traveler Purported Safety

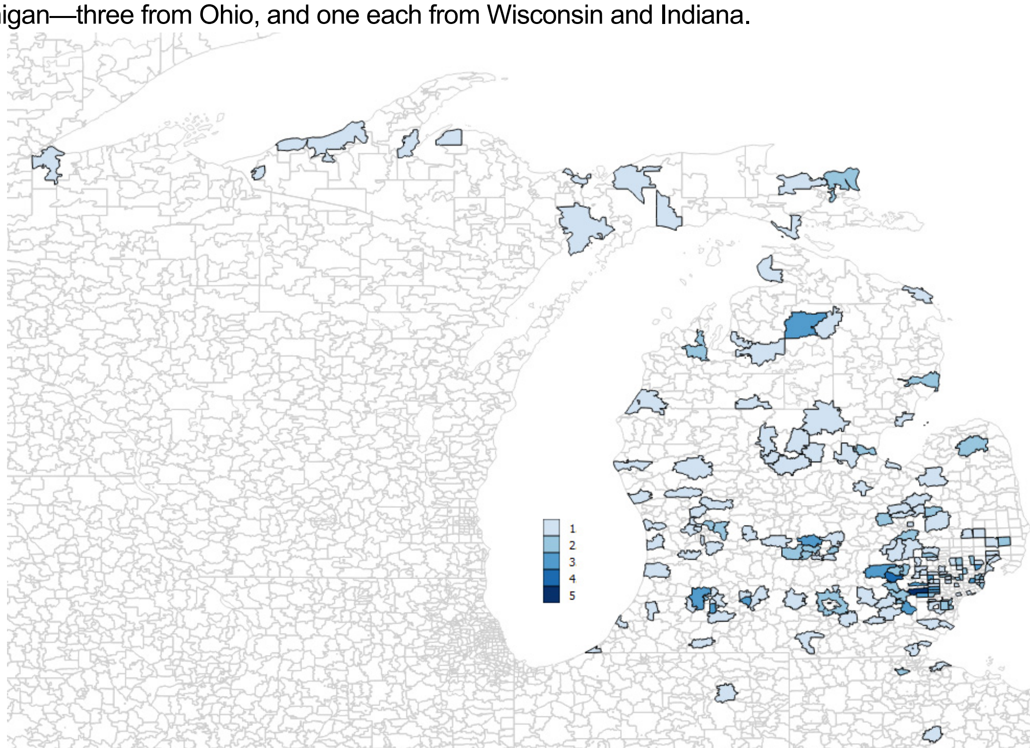
Respondent Questions. *These optional questions were asked to everyone surveyed.* Of the survey respondents that provided demographic information, 58 percent identified as male and 42 percent as female. Table 5-12 shows that males were particularly overrepresented in the 21–35 and over 65 age groups. Males are also overrepresented, though less so, for the 36–50 and 51–65 age groups. Although more females than males responded for the 18–20 age group, the small size of this age group makes it difficult to make any concluding statements regarding this age group.

Table 5-12: Mi Drive Survey Respondent Demographic Cross-Tab

Age	Male	Female
18–20	2	4
21–35	19	10
36–50	40	29
51–65	63	54
Over 65	22	9
Total	**146**	**106**

Source: Battelle, data from MDOT

The map in Figure 5-20 illustrates the locations of respondents who provided their ZIP codes. ZIP codes with more respondents are represented by darker shades of blue. Not surprisingly, a majority of the respondents are clustered near major population centers in southern parts of Michigan (Detroit and vicinity, Flint, Ann Arbor, and Lansing). As can be seen in the image, fewer respondents were noted in the upper-peninsula, and several respondents indicated they live in a ZIP code outside Michigan—three from Ohio, and one each from Wisconsin and Indiana.



Source: Battelle, data from MDOT

Figure 5-20: Mi Drive Survey Respondent ZIP Codes

MOE 2 – Summary of improved traveler perception and value of road weather information
There are many indications from the survey that Mi Drive and DMSs are providing information of value to travelers. Not only does the data show that respondents are using the website to obtain real-time travel information and weather information, but to a certain degree, this information is being used

during the trip planning process. An overwhelming number (95 percent) of respondents who have used the weather information indicate that was very helpful during bad weather conditions. Polling all respondents, roughly half indicated the Mi Drive weather information has resulted in changing the time (47 percent) or route (49 percent) of a trip, while larger percentage of respondents felt more prepared (58 percent). However, despite having used the Mi Drive website or mobile application, a few respondents were not even aware that weather information was available until they had taken the survey (1.4 percent).

A large majority of drivers appear to be aware of DMSs (98.6 percent). A smaller portion of drivers have actually seen a weather-related DMS message since the beginning of 2015 and when the survey was completed—up to May 15, 2015 (76 percent). However, there is an overwhelmingly positive response indicating the DMS road condition and weather information messages make roadways feel safer (88 percent) and reduce delay (75 percent). Furthermore, the weather-related DMS messages displayed appear to impact drivers' reactions. A message indicating a blizzard warning may cause drivers to change their trip plans, while signs displaying road surface condition information (snow covered or slippery roads) are more likely to cause drivers to slow down. In the case of all messages, there was a low likelihood (less than 10 percent) that drivers did nothing (did not change trip or did not reduce speed) in response.

Overall, drivers appear to feel more prepared for adverse weather as a result of the information posted on the Mi Drive website and on DMS. There is slightly more uncertainty regarding the ability of the system to completely alter trip plans. It seems as if drivers must take a trip, or are currently on a trip, the information at least makes them feel prepared, and results in an increased perception of safety and delay reduction.

MOE 3: Increased specificity of traveler information due to weather events

Assessing the specificity of weather-related traveler information first requires defining specificity in the context of weather-related messages. To assess the overall specificity of messages, the total duration of messages during NWS Advisories and Warnings is compared against the total duration of messages outside NWS Advisories and Warnings. This measure provides an indication as to whether or not a message is specific to the current weather condition. Ideally, a larger portion of the weather-related message duration is found when NWS Advisories and Warnings are active. Table 5-13 presents the results of the assessment of weather-related messages during and outside of NWS Advisories and Warnings. In the pre-deployment evaluation period, approximately 27 percent of weather-related messages are displayed during an NWS Advisories and Warnings, while the other 73 percent are not—note that these messages may occur before advisories and warnings, as well as during watches. Despite exhibiting less-intense winter weather, the post-deployment evaluation period saw 36 percent of weather-related messages displayed during NWS Advisories and Warnings. This increase can potentially be attributed to implementing the Wx-TINFO system in Michigan.

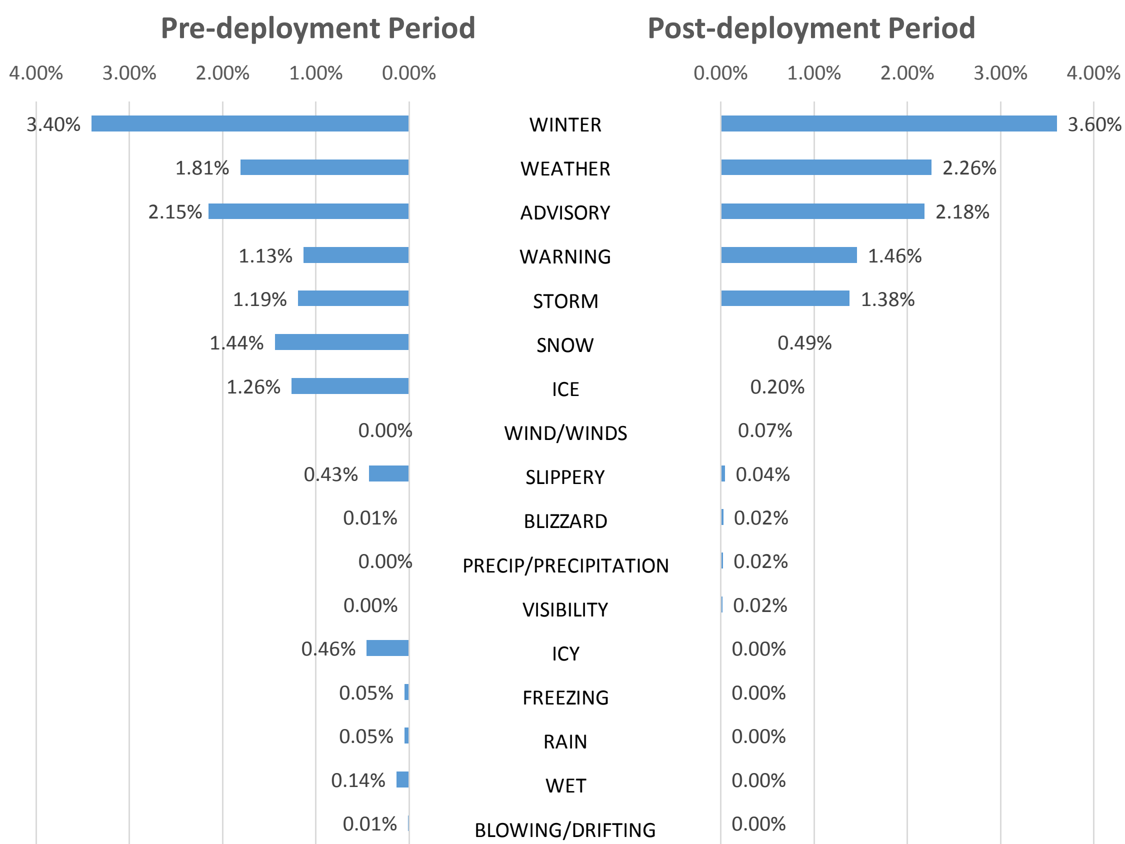
Table 5-13: Weather-Related Message Specificity Assessment

Message Specificity Measure	Pre-deployment Period		Post-deployment Period	
	During alerts	Not during alerts	During alerts	Not during alerts
Hours of Weather-Related Messages	952	2,622	252	448
Percentage of Weather-Related Messages	27%	73%	36%	64%

Source: Battelle, data from MDOT

Another method of measuring specificity is by assessing the usage of words within weather-related messages during NWS Advisories and Warnings. There are many different ways to assess word usage, but for brevity, this section addresses changes in usage of weather-related words and identifies which words saw the largest increase and largest decrease in usage from the pre-deployment evaluation period to the post-deployment evaluation period.

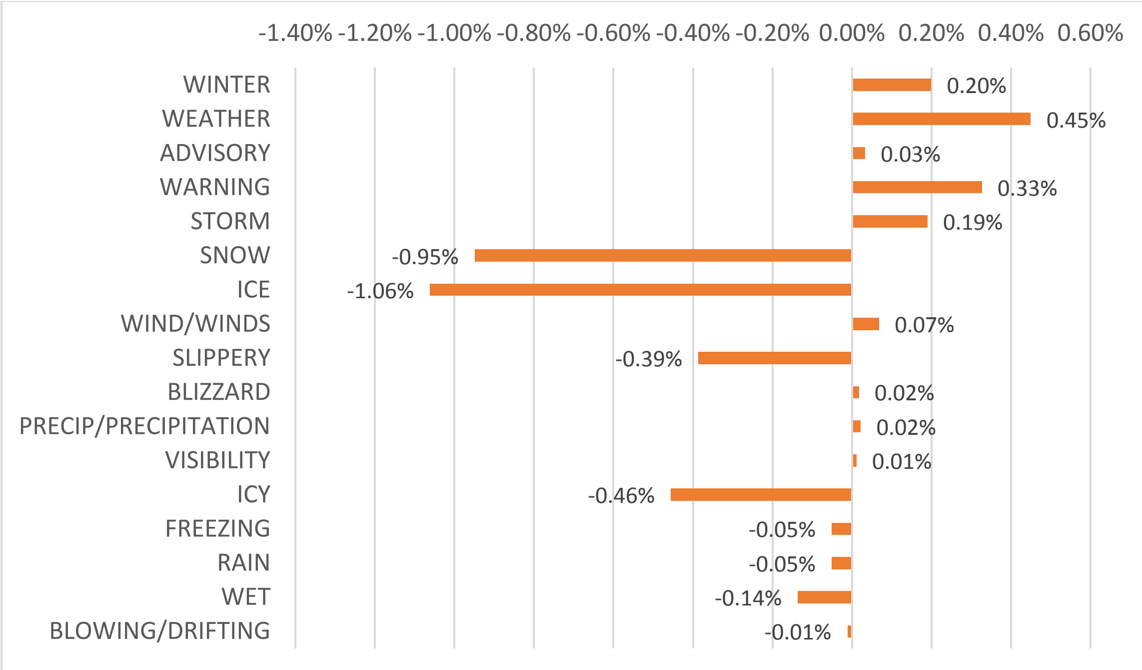
Figure 5-21 lists weather-related terms and the likelihood that the term was used in a message during NWS Advisories and Warnings. Note that terms are in order from most to least used in the post-deployment evaluation period, and terms that did not appear on any DMSs during NWS winter-weather-related alerts are not included. The absolute percentage difference of weather-related term usage is shown in Figure 5-22.



Source: Battelle, data from MDOT

Figure 5-21: Usage of Weather-Related Terms during NWS Advisories and Warnings

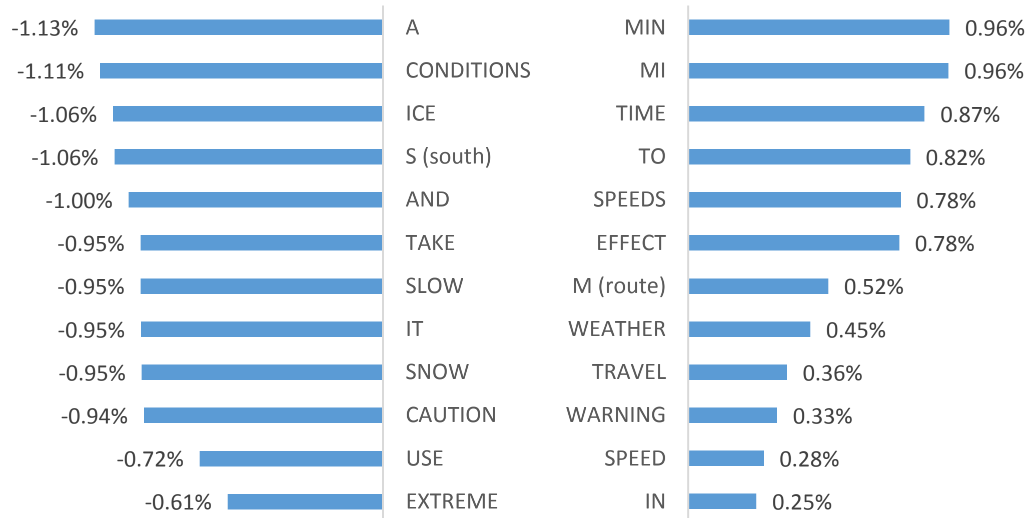
The weather-related terms that see the largest increase in usage include WINTER, WEATHER, WARNING, and STORM while the terms that see the largest decrease in usage include SNOW, ICE, SLIPPERY, and ICY. The terms that see an increase in usage are more specific to NWS Advisories and Warnings. For example, messages like “Ice and Snow Take it Slow” have lessened, while messages like “Winter Weather Advisory” have increased. The terms that see the largest decrease may be due to differences in messaging techniques and/or differences in weather conditions and the spatial distribution of weather from the pre-deployment to post-deployment evaluation period.



Source: Battelle, data from MDOT

Figure 5-22: Change of Usage of Weather-Related Terms during NWS Advisories and Warnings

An assessment of all words within weather-related messages during NWS Advisories and Warnings shows that there are some words that are used much more frequently and some words that are used much less frequently from the pre-deployment to post-deployment evaluation period. The top 12 terms with the largest absolute percentage decrease and increase are shown below in Figure 5-23. The words that show the largest increase in usage, such as MIN, MI, TIME, TO, and SPEED, indicate that more messages are being used to display travel time and speed information during weather events, which is important information to provide to travelers during inclement weather. The words that exhibit the largest decrease in usage appear to indicate a decrease in the number of ICE AND SNOW TAKE IT SLOW and USE EXTREME CAUTION messages. While these messages are important public safety announcements, it is expected that more specific information may be displayed during winter weather conditions during the post-deployment evaluation period.



Source: Battelle, data from MDOT

Figure 5-23: Words with Largest Usage Increase and Largest Usage Decrease during NWS Advisories and Warnings

MOE 4: Reduced incidents during weather events

Weather is a contributing factor in increasing traffic incidents. Ideally, weather-related incidents can be mitigated by improving the timeliness and content of road weather information. For the purposes of this evaluation, it was planned to examine both incidents and crashes. An incident is defined as any event on a road logged in ATMS, whereas crashes are defined as police-recorded vehicle fatalities, injuries, or property damage.

However, crash data for 2015 is not available until the following year (i.e., not yet available), so analysis is provided on incident data only. Furthermore, crash occurrences are highly variable, and three to five years of data are generally required to generate meaningful conclusions. As such, this analysis provides some insight on the system impact on the number weather-related incidents.

One of the more difficult tasks is to determine the precise weather and road conditions that were present at the time the incident occurred. Different types of weather are expected to impact the likelihood of an incident occurring. Ideally, accurate weather and road conditions information is recorded in an incident reporting system. However, the accuracy and thoroughness of incident reports are not necessarily useful for categorizing incidents by weather condition.

It is important to control for the seasonal severity of weather when comparing the pre-deployment evaluation period against the post-deployment evaluation period. As described previously, the duration and spatial properties of NWS watches and warnings are used to control for the severity of the pre-deployment and post-deployment evaluation periods. Also, the evaluation is divided by region to help control for the spatial variability in weather, DMSs, and population density.

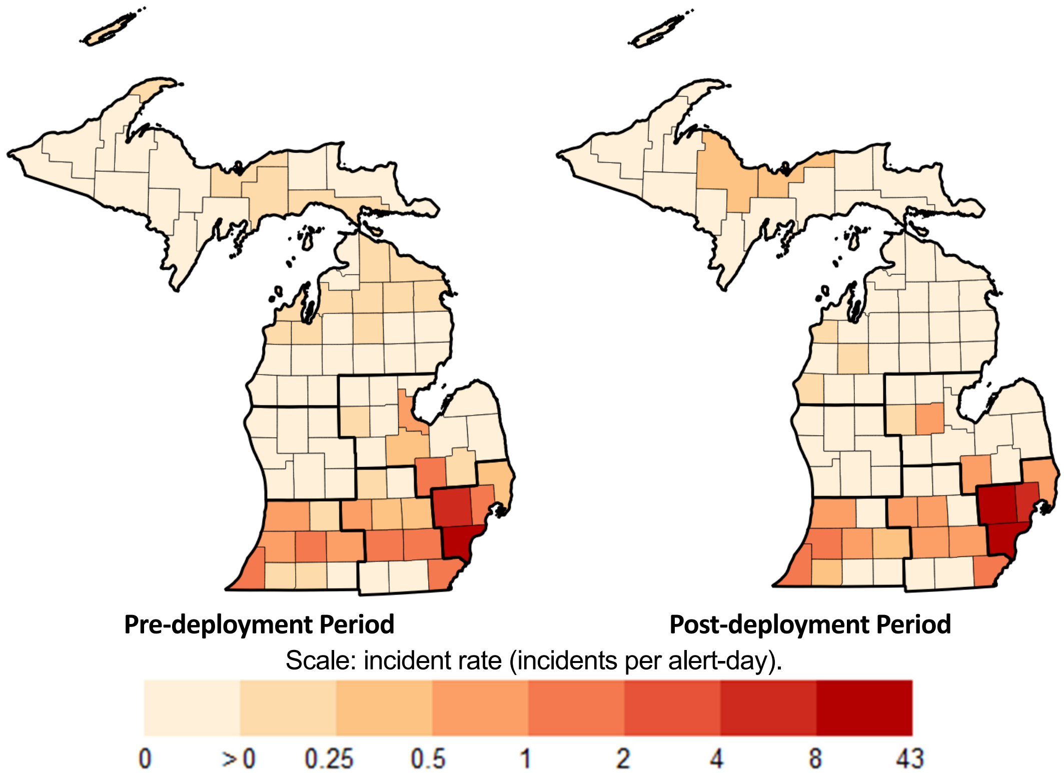
The results of the analysis, including the number of incidents that occur during each alert, the number of alert-days, and the incident rate (incidents per alert-day) are shown for the pre-deployment and post-deployment evaluation periods in Table 5-14. Figure 5-24 shows the incident rate on a county-by-county basis. The results are quite mixed, as the Bay and University regions saw a decrease in the incident rate, while the Metro and North regions saw an increase, and the Southwest and Superior regions remained relatively constant. The county-by-county distribution (in Figure 5-24) appears to show results consistent with the regional analysis, but helps to highlight the variance in incident rates between regions.

Table 5-14: Regional Incident Assessment

Region	Pre-deployment Period			Post-deployment Period			Change
	Number of incidents during alert	NWS alert-days	Incidents (per alert-day)	Number of incidents during alert	NWS alert-days	Incidents (per alert-day)	Percentage change in incidents (per alert-day)
Bay	26	136	0.19	3	26	0.12	-40%
Grand*	873	-	-	251	-	-	-
Metro	210	35	6.06	131	7	17.52	189%
North	15	483	0.03	9	75	0.04	29%
Southwest	148	242	0.61	33	54	0.61	0%
Superior	7	286	0.02	4	37	0.11	3.4%
University	71	129	0.55	12	28	0.42	-23%

* Data not available for Grand region.

Source: Battelle, data from MDOT



Source: Battelle, data from MDOT

Figure 5-24: Incidents per NWS Advisory and Warning Alert-Day (by County)

MOE 5: Decreased travel delays during weather events

Traveler mobility is often impaired by severe weather. Drivers have less control over their vehicle when surface grip is reduced due to snow, ice, or hydroplaning. Furthermore, it becomes more difficult to see the road ahead when visibility is reduced due to the effects of blowing snow, fog, or rain spray. To improve safety, drivers typically slow down in such conditions or will choose not to travel at all. In the case of winter storms, DMS messages may be used to alert motorists of slippery or icy conditions, and maintenance crews work to restore mobility by clearing roads. As previously explained, the Wx-TINFO system is expected to improve mobility by providing messages that alert motorists to hazardous driving conditions, which should reduce delay-inducing incidents. Furthermore, data from the system can assist maintenance crews in identifying routes where weather is expected to impact mobility.

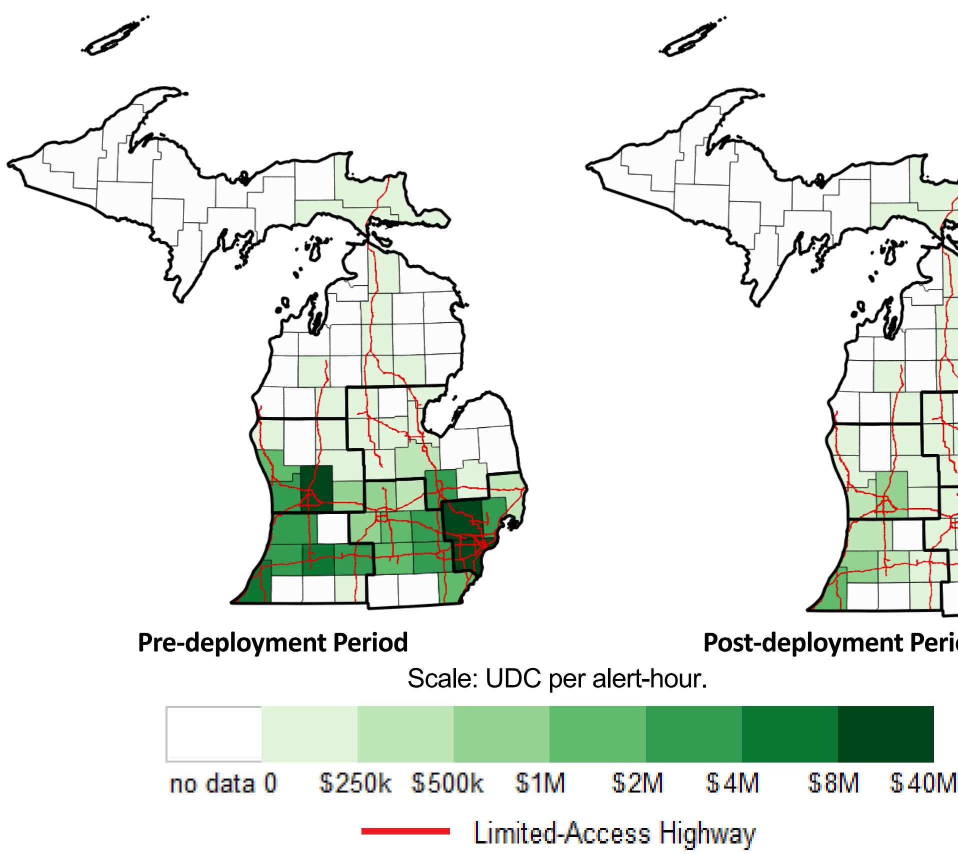
Measuring UDC is an ongoing effort within MDOT. Thus, for this analysis, it is of interest to compare the UDC caused by storms between the pre-deployment and post-deployment evaluation periods. To control for the severity of each evaluation period, the UDC is normalized by the number of NWS Advisory and Warning alert-hours. The resulting measure provides the UDC per storm-hour. Results of the analysis for each region are displayed in Table 5-15 and results on the county level are shown in Figure 5-25. Note that UDC is only available for limited-access highways, shown in red in Figure 5-25. Thus, when performing the regional analysis, only NWS Advisories and Warnings from counties that have UDC data are included.

The table appears to show a large decrease in UDC per alert-hour, which is a promising indication that changes made between the pre-deployment and post-deployment evaluation periods are resulting in a decrease in user delay. Each region saw a decrease of UDC per alert day from 25 to 67 percent. However, the precise cause of this decrease cannot be determined using the data collected, because of differences in storm severity between alerts in the pre-deployment and post-deployment. For instance, weather events associated with a winter storm warning could deliver three inches of snow or twelve inches of snow—each would have a different impact on UDC. Also, weather is not the only factor to impact UDC, but other factors such as incidents and work zones can have impacts.

Table 5-15: Regional UDC Assessment

Region	Pre-deployment Period			Post-deployment Period			Change
	Storm-related UDC	NWS alert-hours	Delay cost (per alert-hour)	Storm-related UDC	NWS alert-hours	Delay cost (per alert-hour	Percentage change in delay cost (per alert-hour)
Bay	$3,922,753	2,814	$1,394	$271,869	548	$496	-64%
Grand	$17,888,225	4,927	$3,631	$1,232,126	1,058	$1,164	-67%
Metro	$56,203,075	1,001	$56,120	$5,837,433	224	$26,058	-53%
North	$589,993	3,480	$169	$37,240	497	$75	-55%
Southwest	$18,649,875	4,098	$4,551	$3,051,638	900	$3,389	-25%
Superior	$59,725	1,402	$43	$3,316	166	$20	-50%
University	$12,589,380	2,957	$4,257	$1,453,157	638	$2,279	-47%

Source: Battelle, data from MDOT



Source: Battelle, data from MDOT

Figure 5-25: UDC per NWS Advisory and Warning Alert-Hour

5.3.2.2 Hypothesis 2 Summary and Conclusions

Hypothesis 2 addresses the ability of the system to improve the timeliness and content of road weather condition reporting updates to the public. Nearly all of the MOEs support this hypothesis. Findings from the assessment of the five MOEs associated with the second hypothesis are listed below.

- A decrease in time for travelers to receive weather-related information through earlier posting of messages was shown in the previous hypothesis. When looking at traveler-specific measures the analysis shows that DMS selections from the Mi Drive website increased for three regions, remained constant for three regions and decreased for one region after system implementation on days when a regional average of one inch of snow or greater was observed. Furthermore, Mi Drive website visits increased by about 20 percent when a statewide average of one inch of snow or greater was observed after system implementation.
- An analysis of customer perceptions shows majority of travelers surveyed are familiar with weather-related DMS messages, respond to the information posted on them (by slowing down or changing trip plans), and feel that they help to improve safety and decrease delay.
- Weather-related messages during NWS Advisories and Warnings are more likely to contain NWS alert terminology and travel times, and fewer general announcements such as ICE AND SNOW TAKE IT SLOW and USE EXTREME CAUTION. Also, weather-related messages are more likely to be displayed during an NWS Advisory or Warning.
- Incident rate decreased for two regions, remained constant for two regions, and increased for two regions.
- User delay costs decreased from 25 to 67 percent statewide during NWS Advisories and Warnings.

Many of the measures indicate confirmation of Hypothesis 2. An increase in DMS selections from Mi Drive, as well as Mi Drive visits, indicate that more information is being viewed by the public during winter weather conditions. The terminology used in weather-related messages during NWS Advisories and Warnings indicates that messages are providing more detailed information that the public is already accustomed to receiving through standardized NWS alerts, ensuring consistent weather information. Since weather-related messages are more likely to be displayed during, and less likely outside, a NWS Advisory or Warning, travelers can have more confidence in the weather-related information being displayed when inclement weather is pending. Also, less delay is experienced by travelers, although it is difficult to attribute this benefit completely to the system. However, there is some room for improvement, particularly in improving traveler safety during winter weather and ultimately decreasing the incident rates.

5.3.3 Hypothesis 3: The system will provide road weather information, which MDOT Maintenance staff perceive as valuable, for possible use in future road weather maintenance operations

Maintenance staff are focused on sustaining safe driving conditions during weather events. It is anticipated that data from Wx-TINFO could benefit maintenance staff by processing customized weather data to provide the locations where weather-related maintenance is needed, thereby enhancing response times and increasing motorist safety. While Wx-TINFO data was not used to support such efforts during the project implementation, it was of interest in exploring the potential to use such data for enhancing future maintenance activities. Maintenance staff members provide insight into how well a prospective Wx-TINFO-based maintenance decision support system might operate in practice. One MOE was used to test Hypothesis 3.

5.3.3.1 Measure of Effectiveness

MOE 1: Perception of capability value by Maintenance staff of weather condition information provided

To assess this MOE, five MDOT Maintenance staff were surveyed in May 2015. The survey was designed to evaluate the perception of the project capability value. Respondents were asked questions regarding how Wx-TINFO data might benefit Maintenance operations. The survey consisted of four questions. Survey questions along with a summary of the responses of those surveyed are listed below.

Question 1 – Would the weather advisory information from the new system help you make better decisions pertaining to maintenance operations?

Two Maintenance staff members felt that the information provided by the new system would allow for better decision making, especially if the data are different, more accurate, or more detailed that what is provided currently in the Maintenance Decision Support System (MDSS).

Two other staff members disagreed stating that the information provided by the new system provides too much information that is not user-friendly, advisory, or intuitive.

One other staff member stated that Maintenance operators use the MDSS to obtain weather information and that the new system could possibly enhance the MDSS by providing more up-to-date and accurate weather information.

Question 2 – If this information is made available in Maintenance vehicles, would Maintenance staff be able to use it to better respond to road weather problem areas or more proactively respond to forecasted weather events?

Only one Maintenance staff member agreed that Maintenance staff would benefit from providing information from the new system in Maintenance vehicles. However, no explanation was provided.

The other four Maintenance staff members responded that providing this information in maintenance vehicles would not be beneficial to maintenance staff. The following reasons were cited:

- May cause more confusion for Maintenance drivers; however, may be useful to the office/garage as a supplement to MDSS information.
- Too many interfaces would be overwhelming. Use the best combination of data, but input into a single interface.

- Would be too much of a distraction and safety concern. Needs to be made simpler and more accommodating to Maintenance needs. Images and alerts are not needed in the cab, unless it can be smart enough to only show what is relevant to the route that the driver is on.
- Distraction to drivers—most drivers already know trouble spots. Not sure what other information we would need on top of what we already receive (e.g., forecasted air and road temps based on roadway type, precipitation type).

Question 3 – Do you think WX-TINFO will help you implement MDSS recommendations for winter Maintenance operations? If not, what other information would be useful in Maintenance vehicles?
Three Maintenance staff members felt that Wx-TINFO could help implement MDSS recommendations. One person mentioned that having DMS information in the same location as the weather information could be helpful to convey accident, travel time, and other unplanned/planned event information to Maintenance workers before or during their activities. Another person noted that the new system would help if it made the data more accurate; however, this person also noted that they had only used each system a few times. The other two staff members said that Wx-TINFO would not help implement MDSS recommendations. One person reasoned that it is important to have only one source of weather information and treatment recommendation and this person is comfortable with the current system.

Question 4 – What additions or improvements to the system would you recommend to make it more useful for maintenance operations?
Additions or improvements to make the system more useful for Maintenance operations included:

- Forecasting capabilities for winter maintenance planning
- Feed data from the new system into MDSS to allow for a single tool.
- When a user selects a date/parameters in one tab (like the map), those parameters need not be reset if selecting other tabs (like reports)
- Playback features need to have buttons so you can go forwards, backwards, and pause
- Legend needs improvements, such as accuracy of temperatures
- The system provides a lot of data, but the site should be able to query longer timeframes, and be more responsive
- Add a tab for Maintenance personnel—most spend limited time in the office. A mobile version might also be useful.

5.3.3.2 Hypothesis 3 Summary and Conclusions

The ConOps proposed that the system could potentially assist Maintenance staff by providing more accurate and detailed weather information. However, given time and budget constraints, MDOT decided that this element of the system would only be investigated at this time and not implemented. The Maintenance staff survey indicates the value such a system could provide during Maintenance operations. In general, some Maintenance staff members had a favorable opinion of the potential of the system, but others felt that the current system was fine. For those who supported the system, improved accuracy and detail was cited as the reason for increased value, while others felt the task of properly interpreting the large quantities of data would be a challenge, and potentially distracting for Maintenance vehicle drivers. If Michigan continues to move forward with integrating the Wx-TINFO system into Maintenance operations, it will be important to take the results of this survey into account, by developing a well-designed decision support system to remove the task of interpreting information from Maintenance staff and to streamline information presented to staff who operate on-road Maintenance equipment.

Chapter 6. Conclusions and Lessons Learned

6.1 Conclusions

Development, implementation, and evaluation of the MDOT Wx-TINFO system resulted in the following conclusions:

1. The use of the MDOT Wx-TINFO system improves the real-time traffic management capabilities of MDOT TOC staff during winter weather events by displaying more weather-related messages with a slightly faster advanced notification time.
2. Majority of TOC staff had a favorable perception of the initial Wx-TINFO system—which was refined based on operator feedback.
3. The benefits to travelers include more specific weather-related information messages and statewide decreases in UDCs during NWS Advisories and Warnings.
4. The web-based Mi Drive survey indicated high scores for familiarity with weather-related messages, responsiveness to weather-related messages, and overall perception of safety and efficiency.
5. The project was very successful in pulling together disparate fixed and mobile data sets and devising operations plans from those data.

6.2 Lessons Learned

The initial implementation of the Wx-TINFO system was a complex undertaking, with the following challenges experienced and addressed by the team.

1. The decision tree logic and thresholds used to define the operation of the system was particularly complex—especially considering the various data inputs and time components. Before deployment, the team was able to test the functionality of Wx-TINFO. The team monitored weather and associated alerts to verify the weather events were reported correctly. Based on the system requirements, the team used DUAP to verify the functionality of the system changes by inspecting closed-circuit television images, NWS radar and observations, and RWIS observations. Analyzing the weather-related data assured the quality of the weather event data that were sent to ATMS.
2. The application was tested for two months by the TOC staff, and their feedback was used to adjust the application. Frequent feedback from TOC Operators allowed developers to incorporate modifications quickly to allow comparisons of changes within the same winter season. Some modifications included:
    a. Adjusting the merging of neighboring winter weather events
    b. Tuning algorithm thresholds to adjust the level of which events were reported
    c. Modifying algorithms to report events more accurately

3. Having SMEs involved in all phases of the project was integral to meeting the requirements of the system and ensuring usability for the operators when it was deployed. Frequent MDOT training webinars were attended by the Lead Operators before and after deploying system changes to ensure those changes were understood and met MDOT's needs.
4. Modifications to the DUAP (Wx-TINFO) system allowed the TOC Operators to view detailed information concerning the weather events being reported by DUAP through ATMS. This provided verification of the weather alerts prior to promoting them to the affected DMSs.
5. The TOC Operator survey was an important piece of feedback. The opinions were mixed, which is not unexpected since the Operators were learning and getting comfortable with a new system in the middle of winter operations. The feedback from the survey identified several high priority items that were quickly revised in the Wx-TINFO system. Other items may be considered for future enhancements to the system.

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

6.3 Next Steps – Future Expansion

The Wx-TINFO system has shown benefits in the initial implementation, and future enhancements should serve to further improve WRTM strategies. MDOT continues to identify and weigh potential changes to the system.

One potential expansion involves having DUAP/Wx-TINFO displayed continuously on the video wall at the Statewide Transportation Operations Center (STOC)—the TOC in Lansing, MI. This would be a project to determine how, by having the map based system available and viewed at all times, the Wx-TINFO information might be leveraged better and add value to the weather decision making process at the STOC.

A second potential modification involves instituting the automatic update of DMS as weather changes. Current operations protocol requires TOC Operators to verify weather events and weather alerts before posting messages. This current protocol, while effective at verification, requires additional time of TOC Operators. Automation could be incorporated into the system to remove the need for operator intervention for message posting.

Chapter 7. Recommendations

Recent implementations of WRTM strategies by transportation agencies have been fairly successful. The MDOT Wx-TINFO System Implementation Project was no exception. MDOT continues to build upon the initial system implementation to improve road weather management. Furthermore, FHWA is continuing its commitment to assisting agencies with WRTM strategy implementations to achieve the goals of the Road Weather Management Program. The following recommendations are intended to assist MDOT and FHWA in their efforts to further advance the WRTM program and facilitate the development and deployment of WRTM strategies.

7.1 Recommendation #1 – Continue Expansion and Addition of MDOT Data Sources

MDOT should build upon the initial implementation by continuing to expand and add data sources into Wx-TINFO. This could include both fixed and mobile data sources. Mobile data sources can continue to be added by equipping MDOT fleet vehicles. Extending the current network of RWIS stations could greatly expand the coverage area thereby increasing the amount of data available for analysis. Outlying areas not frequently traveled by MDOT fleet vehicles equipped for data collection could benefit from the data generated by the additional stations. Nonetheless, even with the current deployment, the RWIS program can provide a wealth of information.

7.2 Recommendation #2 – Continue Outreach and Education of Recent WRTM Strategy Implementation Successes to the Public and Other State DOT's

As a program, WRTM continues to be recognized around the U.S. as a set of strategies that can improve safety and mobility during weather events. The MDOT implementation provides evidence of the potential benefits of WRTM. There may be room for improving the area of outreach, including the possibility of drawing more attention to areas of the Mi Drive website that contain new functionalities, such as enhanced weather information. Additionally, much can still be accomplished to educate and encourage other state DOTs to conduct research and implement strategies that meet their specific needs. Where feasible, MDOT and FHWA should continue to reach out to state DOTs and other agencies to inform them of the WRTM benefits, lesson learned, and future possibilities. This can be accomplished through newsletters and project flyers, presentations at relevant conferences and webinars, and conducting the bi-annual WRTM Workshop.

7.3 Recommendation #3 – Investigate the Expansion of the Wx-TINFO for use in MDOT Maintenance

Since the Wx-TINFO system has been shown to improve TOC Operations and provide benefits to travelers, MDOT should investigate the expansion of the system to provide real-time weather information to MDOT Maintenance. The Wx-TINFO system could be leveraged to provide more accurate and detailed weather information to optimize maintenance activities. The survey of MDOT Maintenance staff indicated that the value such a system could provide during Maintenance operations. Through a thorough needs analysis, MDOT could estimate the benefits of expanding the system for maintenance, such as improved accuracy and detail. If MDOT moves forward with integrating the Wx-TINFO system into Maintenance operations, it will be important to take the results of the maintenance survey into account, by developing a well-designed decision support system to remove the task of interpreting information from Maintenance staff and to streamline information presented to staff who operate on-road Maintenance equipment.

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 generated data are used to improve state DOT operations and traveler information dissemination in different ways. MDOT focused on the integration of improved data acquisition and processing to provide improved operations and traveler information during weather events. MDOT should continue to monitor WRTM activities across the U.S., to identify strategies to improve its own road weather program. For example, the use of road weather condition data for variable speed limits may be an area to investigate. FHWA should continue to monitor and document best practices for WRTM mobile data and connected vehicle applications. Specifically, FHWA should continue to share what is learned or gleaned from state mobile data applications to help promote and encourage of the adoption of similar technology and systems in other parts of the country.

Appendix A. Acronyms

º F .... Degrees Fahrenheit
ASOS .... Automated Surface Observation Systems
ATMS .... Advanced Traffic Management System
AWOS .... Automated Weather Observation Systems
CAN bus .... controller area network
ConOps .... Concept of Operations
DMS .... Dynamic Message Sign
DOT .... Department of Transportation
DUAP .... Data Use Analysis and Processing
ESS .... Environmental Sensor Station
FHWA .... Federal Highway Administration
GIS .... Geographic Information System
GPS .... Global Positioning System
ID .... Identification
IMO .... Integrated Mobile Operations
ITS .... Intelligent Transportation Systems
LCAR .... Lane Closures and Restrictions
MDOT .... Michigan Department of Transportation
MDSS .... Maintenance Decision Support System
MOE .... Measures of Effectiveness
mph .... Miles Per Hour
MTCF .... Michigan Traffic Crash Facts
NCAR .... National Center for Atmospheric Research
NWS .... National Weather Service
QA .... Quality Assurance
QC .... Quality Control
RITIS .... Regional Integrated Transportation Information System
RWIS .... Road Weather Information System
RWMP .... Road Weather Management Program
SME .... Subject Matter Expert
STOC .... Statewide Transportation Operations Center
TOC .... Transportation Operations Center
UDC .... User Delay Cost
UTC .... Coordinated Universal Time
VDT .... Vehicle Data Translator
VIDAS .... Vehicle-based Information and Data Acquisition System
WRTM .... Weather Responsive Traffic Management
Wx-TINFO .... Weather Responsive Traveler Information

Appendix B. MDOT Wx-TINFO Project Evaluation Plan

October 21, 2014

1.0 Introduction

The document describes the evaluation plan for the Weather Responsive Traveler Information System (Wx-TINFO) implementation at the Michigan Department of Transportation (MDOT). This evaluation serves as a way to measure overall program impacts by outlining three evaluation hypotheses, and details the methodology by which each will be tested, including data to be used. The evaluation process will occur during the 2014–2015 winter season, with data collection throughout the winter for the post-deployment experience and data from prior winter experiences as a baseline.

1.1 Project Description

The MDOT Wx-TINFO project will deploy a system to collect both fixed and mobile road weather data and process that data to support traveler information and traffic operations. The system will relay roadway weather information pre-trip or en-route, which will enable the traveling public to make informed travel decisions to improve mobility and safety. Additionally, winter maintenance personnel may use the weather information system in the future to increase efficiency of transportation system treatment. Table B-1 lists the components of the proposed Wx-TINFO system.

Table B-1: Wx-TINFO System Components

Wx-TINFO System
MDOT Advanced Traffic Management System (ATMS)
Mi Drive Web Site
University of Maryland Regional Integrated Transportation Information System (RITIS), with MDOT Lane Closure Activity Report (LCAR) System and HERE (Nokia) System;
Data Use Analysis and Processing (DUAP) System
National Weather Service (NWS) Alerts
Integrated Mobile Observations (IMO) Data Collection System
Environmental Sensor Station (ESS) Road Weather Information System (RWIS)
Vehicle-based Information and Data Acquisition System (VIDAS)

Figure B-1 shows a diagram of the proposed MDOT Wx-TINFO system.

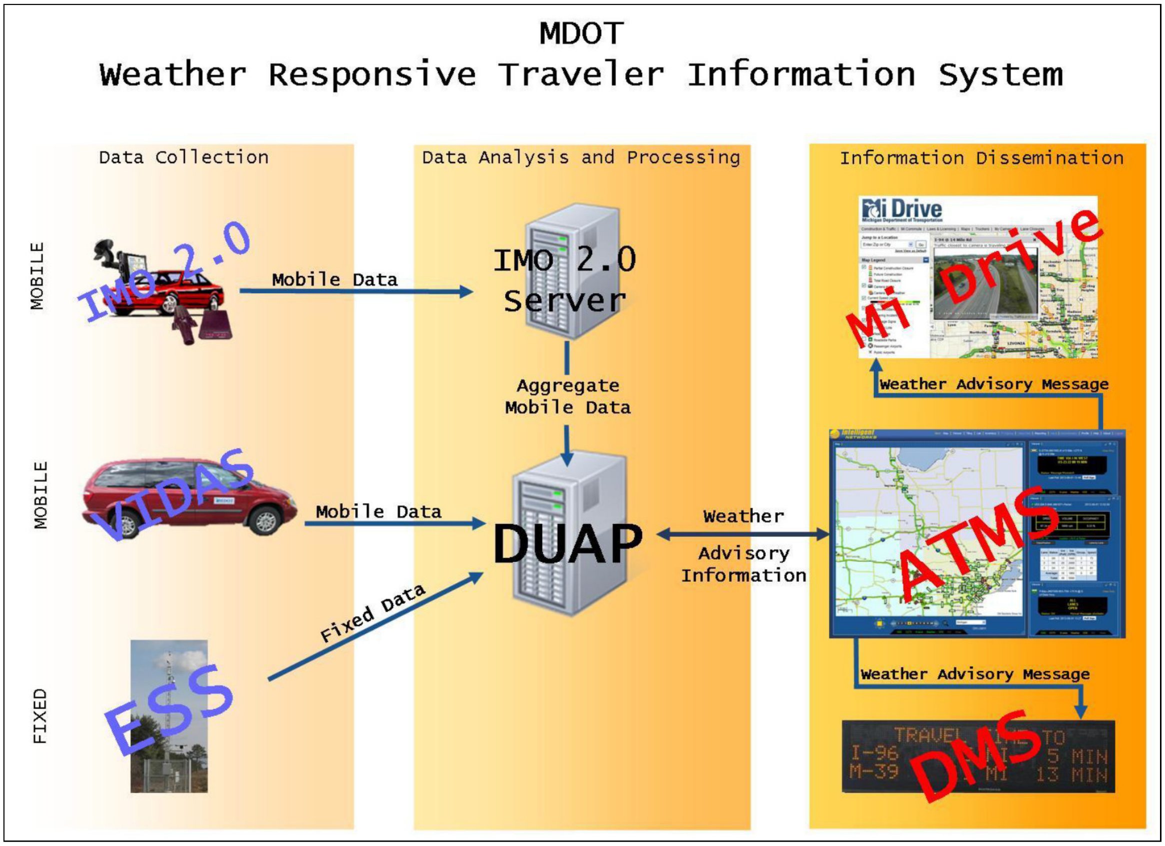


Figure B-1: MDOT Wx-TINFO System Diagram [Source: MDOT]

The MDOT Wx-TINFO system is designed to operate throughout the state. The full deployment of the system will occur in advance of the 2014/2015 winter season.

The data sources for Wx-TINFO include both fixed and mobile observations. The primary coverage of the mobile observations will be the I-94 corridor in southern Michigan where most of the Integrated Mobile Observations (IMO) 2.0 instrumented vehicles are operating. The MDOT Vehicle-based Information and Data Acquisition System (VIDAS) project will also have a number of vehicles collecting mobile observations throughout the entire state, covering all MDOT regions, including a percentage of vehicles in locations with fixed Environmental Sensor Stations (ESS). The primary locations of the ESS for data input will be in the northern Lower Peninsula and Upper Peninsula (MDOT North Region and MDOT Superior Region, respectively, as shown in Figure B-2). As noted in the WRTM proposal from MDOT to FHWA, "*While the fixed and mobile observations primary operational areas are not the same geographically, there is potential to complete structured testing with IMO 2.0 and/or VIDAS instrumented vehicles on roadways instrumented with fixed ESS to provide a base and comparison of weather related advisory messages provided by the two data collection methods, mobile and fixed.*"

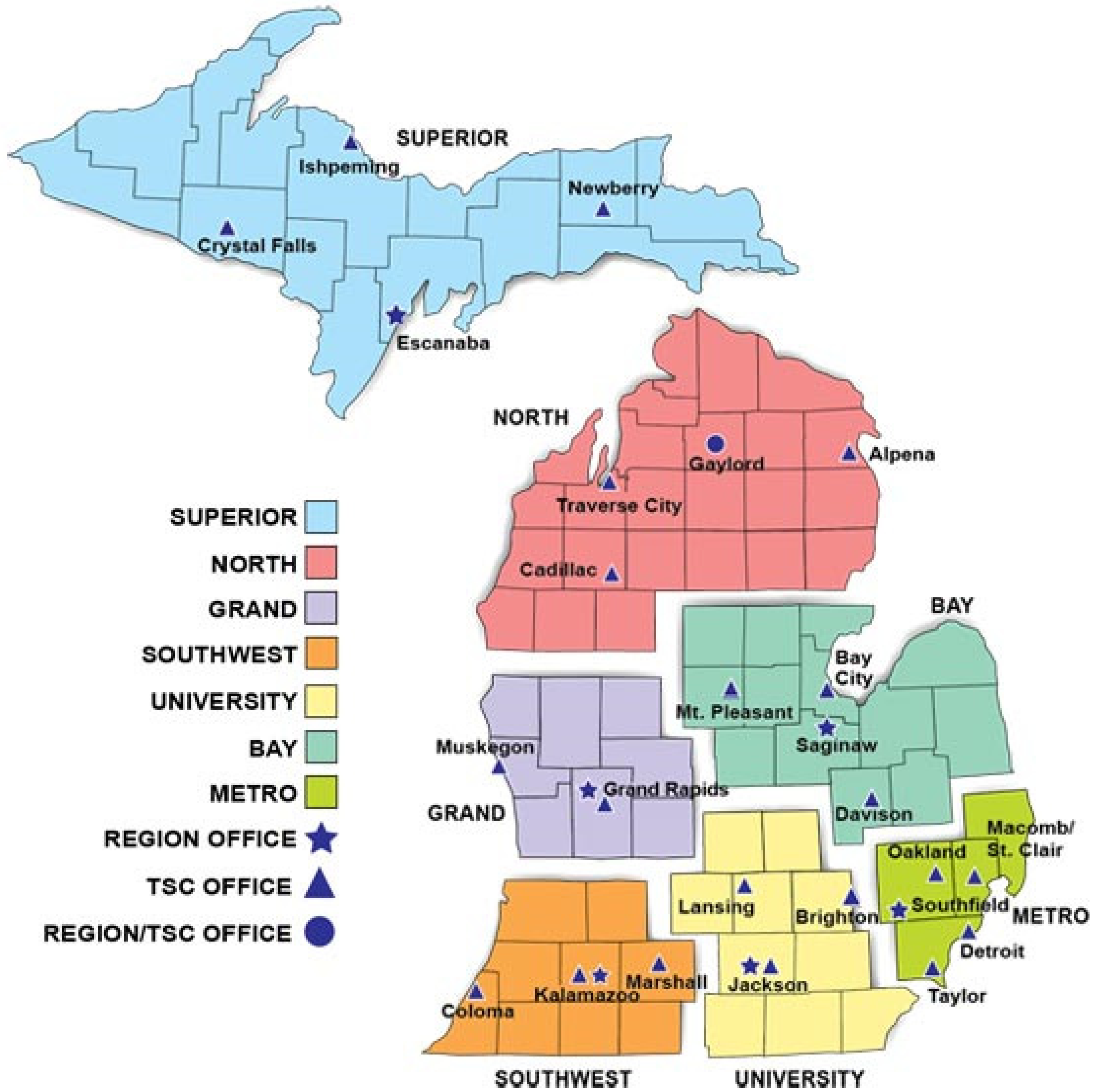


Figure B-2: MDOT Offices by Region [Source: MDOT]

As part of the Wx-TINFO system, the MDOT Data Use Analysis and Processing (DUAP) System, maintained and operated by MDOT contractors, will aggregate and synthesize the data to identify weather related information, including event type, location, and safety recommendations. The information will then be disseminated to the various stakeholders.

The weather advisory information will be communicated through a variety of media, such as MDOT's dynamic message signs (DMS) (using ATMS software) and Mi Drive web site (http://mdotnetpublic.state.mi.us/drive/).

Table B-2 summarizes the expected benefits of the Wx-TINFO system described in the MDOT Wx-TINFO ConOps document.

Table B-2: MI Wx-TINFO System Expected Benefits

System User	Expected Benefit
MDOT TOC Operations	• Deliver traffic information to the traveling public via DMS and Mi Drive through ATMS Operators on a timely basis. • Improve agency efficiency and productivity by avoiding redundant data collection and processing activities. Having the ability to collect, combine, and share both mobile and fixed environmental/weather, traffic, and asset condition data can improve traffic operations
Traveling Public	• Improved safety and mobility by improving driver awareness of road conditions and assist drivers in making informed decisions to alter their route, plan extra time for a trip, or cancel their trip. Example scenarios include: o Advanced warnings of severe storms (time and location) for travel modification. o Improved roadside DMS messages and information on the Mi Drive web site.
MDOT Maintenance	• Potentially improve the ability of Maintenance crews to identify road weather problem areas and respond proactively to forecasted events

1.2 Objectives of Evaluation

This detailed evaluation plan is designed to evaluate the following hypotheses:

- The system will improve the (real-time) traffic management capabilities of MDOT TOC Operations staff during weather events.
- The system will improve the timeliness and content of road weather condition reporting updates to the traveling public.
- The system will provide road weather condition information, which MDOT Maintenance staff perceive as valuable for possible use in future road weather maintenance operations.

1.3 Document Organization

The remainder of this report is divided into three sections. Section 2.0 outlines the evaluation approach, which includes detailed descriptions of how to test each of the three project hypotheses. Section 3.0 lists the risks inherent in evaluating the project, as well as strategies to mitigate them. Section 4.0 outlines the evaluation schedule and provides an itemized action plan for evaluation preparation. Section 5.0 describes the evaluation roles and responsibilities.

2.0 Evaluation Approach

This section describes the evaluation approach to be used to measure the MDOT Wx-TINFO project benefits. It includes a discussion of how the hypotheses will be measured and identifies specific measures of effectiveness (MOEs), the data needed to support the analyses, and the analysis to be conducted to test each hypothesis.

Table B-3 provides a summary of the pertinent information to guide the evaluation. Hypotheses, MOEs, and data elements are listed. The evaluation will use both quantitative and qualitative analyses to test the hypotheses.

Table B-3: Linkage between Hypotheses, MOEs, and Data Elements

Hypothesis	MOE	Data Elements
Hypothesis 1: The system will improve the real-time traffic management capabilities of MDOT TOC Operations staff during weather events.	• Increased number of reported significant weather events. • Decreased response time to post and update travel impacts due to weather events. • Improved perception of value by TOC Operators.	• NWS - Weather Events, Time Alert issued • Wx-TINFO and DUAP - Weather Events, Time Alert sent to ATMS • ATMS Logs - Weather Events posted on DMS, Time Alert Posted • Mi Drive Logs - Weather Events posted on Website, Time Alert Posted • Survey of TOC Operators
Hypothesis 2: The system will improve the timeliness and content of road weather condition reporting updates to the traveling public.	• Decreased time for travelers to receive and respond to travel impacts due to weather events. • Improved perception of road weather information value from travelers. • Increased specificity of traveler information due to weather events. • Reduced incidents and crashes during weather events. • Decreased travel delays during weather events.	• NWS - Time Alert issued, Weather Event Time Period • Wx-TINFO and DUAP - Time Alert sent to ATMS • ATMS Logs - Time Alert and Content Posted on DMS, Number of Weather-Related Incidents and Max Delay during weather event • Mi Drive Logs - Time Alert and Content posted on Website, quantity and Time Alert clicked • RITIS and LCAR - Number of Weather-Related Incidents and Max Delay during weather event • MTCF - Number of Weather-Related Incidents during weather event • Survey of Travelers' Perceptions
Hypothesis 3: The system will provide road weather condition information, which MDOT Maintenance staff perceive as valuable, for possible use in future road weather maintenance operations.	• Perception of capability value by Maintenance staff of weather condition information provided.	• Survey of Maintenance staff.

Quantitative data collection efforts will be finalized based on direction from MDOT and the analysis approach selected. These efforts are likely to focus on several analogous winter events from November 1 through April 30 in the 2013–2014 and 2014–2015 winter seasons. The evaluation team will work with the identified MDOT representatives to ensure sufficient data is received to conduct the analysis in a comprehensive manner. Additionally, qualitative surveys or interview questionnaires will be developed for implementation or distribution, respectively, at the end of the 2014–2015 winter season to gather input from affected stakeholders.

In addition to the data listed in Table B-3, measures will be collected to account for other factors besides the Wx-TINFO system itself that could influence the evaluation results. First, winter weather severity will be monitored to control for any differences caused by dissimilar weather conditions that might impact the evaluation MOEs. Second, changes made to the Wx-TINFO System 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.

The analysis methods will include both 'before-after' and 'with-without' approaches, as well as numerical/statistical techniques. Descriptions of these possible approaches for evaluating the Wx-TINFO System are explained below:

- A 'before-after' comparison of selected similar winter events in two winter seasons from the same MDOT region, where the Wx-TINFO System was in use for the 2014–2015 season. The before-after analysis method will require that previous year data be available from which to make a comparison.
- A 'with-without' comparison of two MDOT regions: one that has greater coverage of mobile and fixed ESS data compared against a second region 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 regions).

A bulk of quantitative data analysis will require archived ATMS logs, Wx-TINFO/DUAP logs, Mi Drive logs, RITIS (LCAR logs), Michigan Traffic Crash Facts (MTCF) query tool, and the NWS alert archive. It is expected that these logs include time stamped data entries, including information for when messages are received and when DMS and Mi Drive are updated for disseminating the information to MDOT employees and the general public. These time stamps will be examined for differences in time with and without the Wx-TINFO System (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 Wx-TINFO System.

In order for the evaluation to track the evolution of the Wx-TINFO System through the winter season, it is expected that the dates for implementing any modification or revision to the system 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 system that might likewise improve performance.

Qualitative data will also be used to support the findings of the quantitative data analysis. A series of surveys or interviews will be conducted with Maintenance employees, TOC Operators, and travelers to assess their perceptions of impacts of the Wx-TINFO System. These surveys and interviews will gather the user perceptions of accuracy of storm severity information and traveler response instructions. Surveys or interview guides will be developed in late 2014 for approval and input by MDOT before being conducted twice during the evaluation period. The first round will occur immediately after the training is completed for the TOC Operators and Maintenance employees at the beginning of the winter to gather initial expectations and any bias towards the Wx-TINFO System. The second wave will be towards the end of the 2014–2015 winter season and capture the evolution of the perceptions on the part of the TOC Operators and Maintenance employees.

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

Hypothesis 1: The system will improve the (real-time) traffic management capabilities of MDOT TOC Operations staff during weather events.

MDOT Operations staff are critical in providing motorists with valuable information during weather events. Currently, MDOT Transportation Operations Centers (TOCs) can become overwhelmed with incidents that occur during winter weather events. This hypothesis tests if the system provides improved information to TOC Operators on relevant weather-related advisory or alert locations and if this improves and/or increases real-time distribution of traffic management information.

Evaluation of the system will be based upon MDOT's ability to manage traffic during weather events. This could be done in a number of ways including:

- Increased number of reported significant weather events.
- Decreased response time to post and update travel impacts due to weather events.
- Improved perception of value by TOC Operators.

It is planned that a combination of the before-after and with-without analysis methods will be used to test this hypothesis, depending upon data availability and MDOT input to determine the most accurate and effective approach.

The before-after and with-without methods will be used to analyze the increase in number of weather-related events. This MOE will use quantitative data from the NWS, Wx-TINFO, ATMS, and Mi Drive systems to compare the number of events before-after the implementation of Wx-TINFO and with-without ESS or mobile data across different MDOT regions.

Similarly, the before-after and with-without methods will be used to analyze the decrease in the response time to post and update travel impacts due to weather events. This MOE will use quantitative data from the NWS, Wx-TINFO, ATMS, and Mi Drive systems to compare the time from the NWS weather alert to the alert posting before-after the implementation of Wx-TINFO and with-without ESS or mobile data across different MDOT regions.

Lastly, the before-after method will be used to analyze improved perception of value by TOC Operations staff. This MOE will use qualitative data from Operator surveys before-after the implementation of Wx-TINFO.

Hypothesis 2: The system will improve the timeliness and content of road weather condition reporting updates to the traveling public.

Currently, MDOT does not provide specific road weather-related traveler information to motorists in the form of advisories or alerts. This is due to the fact that the functionality does not currently exist to collect data in real-time, process and provide a user accepted or automated message via ATMS to the Mi Drive traveler information website or roadside DMS. This project will give MDOT the ability to demonstrate how providing motorists with more timely and more valuable road weather information allows them to make safer and more timely decisions both pre-trip and en-route in relation to traveling the road network in inclement weather conditions. This hypothesis tests if the information provided to motorists improves their mobility and safety during adverse weather conditions.

The evaluation of the pre-trip and en-route traveler information system for enhancing traveler decisions to improve mobility and safety could be measured by:

- Decreased time for travelers to receive and respond to travel impacts due to weather events
- Improved perception of road weather information value from travelers
- Increased specificity of traveler information due to weather events
- Reduced incidents and crashes during weather events
- Decreased travel delays during weather events

It is planned that a combination of the before-after and with-without analysis methods will be used to test this hypothesis, depending upon data availability and MDOT input to determine the most accurate and effective approach.

The before-after and with-without methods will be used to analyze the decrease in time for travelers to receive and respond to travel impacts due to weather events. This MOE will use quantitative data from the NWS, Wx-TINFO, ATMS, and Mi Drive systems to compare the time from the NWS weather alert to the alert posting before-after the implementation of Wx-TINFO and with-without ESS or mobile data across different MDOT regions.
The before-after method will be used to analyze improved perception of road weather information value from travelers. This MOE will use qualitative data from traveler surveys before-after the implementation of Wx-TINFO.

The before-after and with-without methods will be used to analyze the increase in specificity of traveler information due to weather events. This MOE will use quantitative data from the ATMS and Mi Drive systems to compare the content of weather-related messages before-after the implementation of Wx-TINFO and with-without ESS or mobile data across different MDOT regions.

The before-after method will be used to analyze the reduction in incidents and crashes during weather events. This MOE will use quantitative data from the NWS, ATMS, RITIS (LCAR), and MTCF systems to compare the number of weather-related incidents and crashes during the weather alert time period before-after the implementation of Wx-TINFO. This MOE may not be able to demonstrate differences and/or causation due to the limited number of crashes. Roadway safety studies generally use a period of at least three years to make such determinations.

The before-after and with-without methods will be used to analyze the decrease in travel delays during weather events. This MOE will use quantitative data from the NWS, ATMS, and RITIS (LCAR) systems to compare the maximum delay during the weather events during the NWS weather alert periods before-after the implementation of Wx-TINFO and with-without ESS or mobile data across different MDOT regions.

Hypothesis 3: The system will provide road weather condition information, which MDOT Maintenance staff perceive as valuable for possible use in future road weather maintenance operations.
MDOT maintenance activities are critical in providing motorists with safe driving conditions during weather events. Currently, MDOT maintenance staff can become overwhelmed with maintenance activities (plowing, salting, etc.) during winter weather events. Having the ability to utilize Wx-TINFO system to potentially advise maintenance staff of necessary winter maintenance locations including real-time unsafe pavement/roadway conditions might enhance response times, and thereby increase motorist safety. MDOT does not propose to implement this capability at this time, but instead seeks to investigate the perceived benefit of implementing this capability in the future. This hypothesis tests if providing customized weather information through Wx-TINFO to Maintenance personnel would be viewed positively by them.

The evaluation of this potential system capability will be based on the data provided to MDOT maintenance personnel and could be measured by:

- Perception of capability value by maintenance staff of weather condition information provided.

The before-after method will be used to analyze perception of capability value by maintenance employee of weather condition information provided. This MOE will use qualitative data from maintenance employee surveys before-after the implementation of Wx-TINFO.

3.0 Risks and Mitigations

Table B-4 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 B-4: Potential project challenges and constraints and strategies used to mitigate them

Risks	Mitigation Strategy
1. There is a learning curve associated with any new technology. TOC Operators might take time becoming accustomed to new procedures.	The Wx-TINFO system should be complete well before the start of the winter season, giving TOC Operators time to become accustomed to associated new procedures in the ATMS. MDOT intends to perform training for TOC Operators and maintenance employees prior to the 2014-15 season start as required. For maintenance employees and TOC Operators, the first wave of survey questions will try to gauge whether they are becoming more comfortable with the technology.
2. The amount of time it takes for a roadside device or information system to be updated can be dependent on the expertise of the TOC Operator. TOC employee 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.
3. Employees might not feel able to share criticism of a project supported by their supervisors.	Employees will have the ability to make anonymous comments.
4. The state's new DMS Guide is not yet complete. If it is not done, and the Attorney General (AG) has not approved a standard message library before the storm season, there may be additional variability in messages throughout the state.	If the new DMS Guide is not in place, the TOCs will be asked to help provide the full DMS message library.
5. 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 MDOT representatives to identify usable data and alternatives where any identified data element is missing in order to perform a complete analysis.
6. 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.

4.0 Evaluation Schedule

The finalized evaluation plan will be completed in October 2014, and evaluation activities will begin in October 2014, after the ITS World Congress demonstration. A detailed evaluation task schedule is shown in Table B-5.

Table B-5: Evaluation schedule by task

Task	Completion Dates
Complete Evaluation Plan and Brief MDOT Stakeholders	October 2014
Begin Limited Quantitative Data Collection for 2013–2014 Winter Season	October 2014
Quantitative Data Collection for 2014–2015 Winter Season	Nov 2014 – April 2015
Conduct Debrief and Distribute Stakeholder Surveys	[after first winter event]
Conduct Preliminary Quantitative Comparative Analysis	Nov 2014 – Jan 2015
Submit Preliminary Analysis Findings	Feb 2015
Conduct Quantitative Analysis	Feb 2015 – April 2015
Distribute Stakeholder Surveys	March 2015
Conduct Qualitative Analysis	April 2015 – May 2015
Conduct Final Analyses and Document	June 2015 – August 2015
Submit Final Evaluation Report	August 2015

5.0 Evaluation Roles and Responsibilities

The execution of the evaluation activities described in this plan will be a joint effort conducted by MDOT and the FHWA Technical Support Contractor (Battelle). 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 MDOT's contractor-developed Concept of Operations and several discussions with MDOT and contractor project staff, Battelle prepared this document and it was reviewed and approved by MDOT.

In general, the data collection will be the responsibility of MDOT and the analysis and development of the evaluation report will be the responsibility of Battelle. Specifically, the responsibilities are outlined in Table B-6.

Table B-6: Responsibilities during Evaluation Plan Execution

	Michigan DOT			Battelle		
Activity	Primary	Secondary	Review	Primary	Secondary	Review
Present evaluation approach to MDOT staff ahead of project rollout.			●	●		
Review and ensure identified data sources provide needed data.	●					●
Develop surveys and interview guides for TOC Operators and Maintenance employees.		● (1)	●	●		
Collect and provide needed data, per evaluation plan.	● (2)					●
Conduct surveys and interviews with involved MDOT staff and travelers, per evaluation plan. Provide results.	●				● (3)	
Analyze data to test hypotheses and draw conclusions.		● (4)		●		
Document results in Evaluation Report.			●	●		

Notes:

(1) Contribute input and questions for survey and interview guide development
(2) Refer to Table B-3 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

Appendix C. Traveler Information Survey

Michigan DOT Weather Responsive Traveler Information System (Wx-TINFO) Project
Traveler Information Survey
March 30, 2015 to May 15, 2015

Background
You are invited to participate in a survey to evaluate the effectiveness of new road weather information provided by Michigan Department of Transportation (MDOT) in promoting safety and mobility of travelers in Michigan during inclement weather conditions. This includes information available before and during your trip. Your responses will help MDOT enhance the use of weather information in Michigan. It will take approximately five minutes to complete the questionnaire.

Your participation is completely voluntary and the survey responses will be strictly confidential. Individual responses will be combined with others for reporting purposes. If you have any questions on this survey, please email Mr. Collin Castle of MDOT at CastleC@michigan.gov.

Thank you for your time and support. Please start the survey now by clicking on the Continue button below.

Weather Information Questions

1. How often do you use the Mi Drive website to get real-time traveler information before you make a trip?
    a. Never (0 times) *[if this answer is selected – skip to question 4]*
    b. Rarely (<1 time per month)
    c. Sometimes (1-4 times per month)
    d. Often (1-5 times per week)
    e. Very frequently (>5 times per week)
2. Do you use the weather information available on the Mi Drive website?
    a. Yes
    b. No *[if this answer is selected – skip to question 4]*
3. How useful to you is the weather information available on the Mi Drive website during bad weather conditions?
    (Use the following scale: Very Useful, Somewhat Useful, Not Useful, Don't Know)
4. Please indicate the degree to which the Mi Drive weather information has affected your trips during bad weather conditions?
    (Use the following scale: Strongly Disagree, Disagree, Agree, Strongly Agree, Don't Know)
    a. I have changed the timing of one or more trips
    b. I have changed the routing of one or more trips
    c. I have felt more prepared for one or more trips
    d. Other (please explain):
    [Text box for user input.]

5. Are you familiar with Michigan's Dynamic Message Signs (DMS), such as those pictured above?
    a. Yes, I know them well.
    b. I am aware of them, but do not know them well.
    c. No, not at all.
6. How many weather-related DMS messages have you seen this year (2015)?
    a. 0
    b. 1-5
    c. 6-10
    d. 11+

In questions 7 through 9 if you have seen (or if you were to see) the following messages on a DMS as you were driving, did you (or would you) slow down and pay more attention to the roadway, or change your trip?

7. SNOW COVERED ROADS
   ON I-96 AND I-94
    a. Saw DMS and did not slow down or change my trip (nor would have, if seen)
    b. Saw DMS and did slow down (or would have, if seen)
    c. Saw DMS and did change my trip (or would have, if seen)
    d. Saw DMS and did slow down and change my trip (or would have, if seen)
8. BLIZZARD WARNING
    a. Saw DMS and did not slow down or change my trip (nor would have, if seen)
    b. Saw DMS and did slow down (or would have, if seen)
    c. Saw DMS and did change my trip (or would have, if seen)
    d. Saw DMS and did slow down and change my trip (or would have, if seen)
9. SLIPPERY ROADS
   REDUCE SPEED
    a. Saw DMS and did not slow down or change my trip (nor would have, if seen)
    b. Saw DMS and did slow down (or would have, if seen)
    c. Saw DMS and did change my trip (or would have, if seen)
    d. Saw DMS and did slow down and change my trip (or would have, if seen)
10. Do these types of DMS messages about road condition and weather information make you feel safer as you drive?
    a. Definitely – I feel much safer as I drive after seeing these types of DMS messages.
    b. Somewhat – I feel a little safer as I drive after seeing these types of DMS messages.
    c. Not at all – I do not feel safer as I drive after seeing these types of DMS messages.

11. Do you think these types of DMS messages about road condition and weather information reduce travel delays?
    a. Definitely – I think these types of DMS messages often reduce travel delays.
    b. Somewhat – I think these types of DMS messages sometimes reduce travel delays.
    c. Not at all – I do not think these types of DMS messages reduce travel delays.
12. Please give an example of other weather-related DMS messages that you would find useful for road condition and weather information.
    [Text box for user input.]
13. Do you have comments or suggestions for the DMS system? Answer does not need to be weather related.
    [Text box for user input.]

Respondent Questions (Optional)

14. How did you find out about this survey?
    a. While exploring information on Mi Drive
    b. Invited by e-mail request
    c. Other:
       [Text box for user input.]

15. Please enter your home zip code:
16. What is your gender?
    a. Male
    b. Female
17. What is your age?
    a. 18-20
    b. 21-35
    c. 36-50
    d. 51-65
    e. Over 65
18. Please provide your contact information if you are willing to be contacted regarding your comments:
    a. First Name:
    b. Last Name:
    c. Phone:
    d. E-mail Address:

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