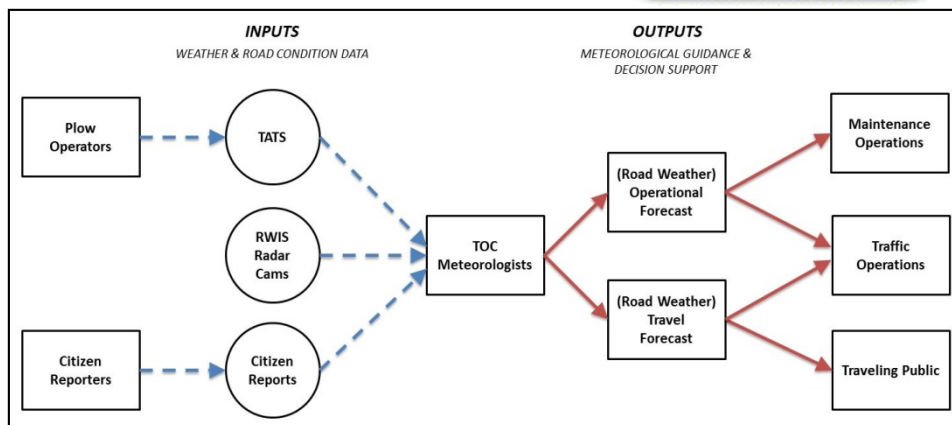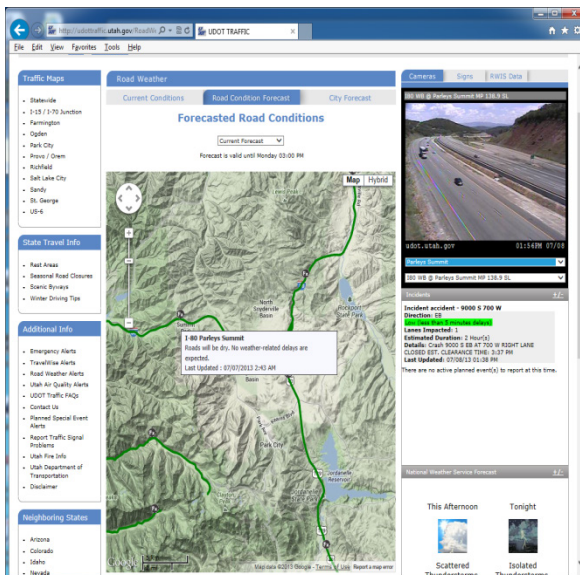# Utah DOT Weather Responsive Traveler Information System

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Final Report — September 13, 2013
FHWA-JPO-13-089

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Notice

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Over the past decade, the Federal Highway Administration's (FHWA) Road Weather Management Program (RWMP) has championed the cause of improving traffic operations and safety during weather events. The program's current emphasis is to encourage agencies to be more proactive in the way that they manage traffic operations during bad weather. Weather Responsive Traffic Management (WRTM) is a component major element of the program. WRTM involves the implementation of traffic advisory, control, and treatment strategies in direct response to or in anticipation of developing roadway and atmospheric problems that result from deteriorating or forecasted weather conditions. WRTM also includes using weather forecasting to provide proactive advisory and control strategies based on forecasts of weather conditions, and not just traffic responses to those conditions.

In 2011, the RWMP initiated a project to collate recent developments and best practices in WRTM, identify improvements to the strategies, and develop implementable Concepts of Operations. As a follow-on task, three concepts were selected for further implementation and real-world deployment. This report documents the implementation of one of those concepts relating to weather responsive traveler information. This concept focused on an initial implementation of a citizens reporting system and was conducted in partnership with Utah DOT. This report documents the system design, operation, evaluation, findings and lessons learned from the implementation.

Considering this was the first opportunity to implement a limited citizen reporting program, the results are encouraging. Fifty-six UDOT employees were trained, 89 of 143 road segments were covered, and 607 reports were submitted during the 2012/2013 winter season. Report accuracy was very high (over 99%), and they provided increased situational awareness for TOC meteorologists and operators. Public response to this program was quite positive. Lessons from this initial implementation will help UDOT further develop and move this program forward and serve as a valuable model for other state DOTs that seek to implement similar improvements.

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- Lisa Miller – Traveler Information Manager and UDOT Project Manager
- Glen Blackwelder – TOC Traffic Engineer
- Jeff Williams – Lead Meteorologist
- Justin Connolly – Traveler Information Meteorologist
- Chuck Felice – Electronic Business Project Manager

Several other UDOT staff was also involved in various stages of the project, from the concept of operations to systems development, training and evaluation. We appreciate all their contributions to this project.

A special thanks is extended to Leigh Sturges (Narwhal Met, LLC) for her efforts leading the project evaluation task, collecting and analyzing data, and writing Chapter 5, Evaluation Results.

Finally, thank you to Roemer Alfelor of the Road Weather Management Program for his ongoing support of this effort and technical guidance and direction throughout this WRTM implementation project.

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Executive Summary

Introduction and Background

Weather Responsive Traffic Management (WRTM) involves the implementation of traffic advisory, control, and treatment strategies in direct response to or in anticipation of developing roadway and visibility issues that result from deteriorating or forecasted weather conditions. WRTM also includes using weather forecasting to provide proactive advisories and control strategies based on forecasts of weather conditions, and not just the results of those conditions. The Federal Highway Administration's (FHWA) Road Weather Management Program (RWMP) has, as one of its primary focus areas, been encouraging the development and implementation of WRTM strategies. This report specifically addresses a recent implementation of a WRTM strategy in Utah: Road Weather Traveler Information System.

In 2011, the RWMP initiated a project to document existing strategies for WRTM, identify improvements to the strategies, and develop implementable Concepts of Operations for the improved strategies. A ConOps was developed for several different WRTM strategies, including weather responsive pre-trip and en-route traveler information. Several States expressed interest in participating in this project, and Utah DOT was the partner selected to implement a traveler information strategy. UDOT already has one of the most sophisticated Traffic Operations Centers (TOCs) in terms of how they obtain and integrate road weather information in traffic management decisions. The UDOT Weather Responsive Traveler Information System implementation project set out to make significant improvements in the current operations activities in an effort to improve the timeliness and accuracy of the information provided to travelers. Specific objectives were to:

- Increase the frequency of weather forecasts from 6 hour increments, 18 hours in the future (3 forecasts) to 3 hour increments, 24 hours in the future (8 forecasts).

- Provide road weather forecasts to 6 additional state routes of significance (US-191, US-89, US-189, SR-20, SR-210, and SR-190 (this is in addition to the 7 interstates and US highways already receiving public forecasts).

- Develop and implement an initial citizen reporting system. This system will use the current UDOT Traffic smartphone applications to allow citizens to report back to UDOT conditions on their roadways (for the initial system, a separate smartphone citizen reporting app was developed). The initial implementation included UDOT employees only – each reporter was trained on how to record observations and submit reports.

- Make appropriate software changes to manage the additional data and forecasts and disseminate them to travelers using the UDOT Traffic website, 511 phone system, and smartphone applications.

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The primary goal of the Utah DOT Weather Responsive Traveler Information project was to provide both TOC operators and travelers with more accurate and timely road weather and travel impact condition information and forecasts. The currency and resolution of road weather observations and road weather forecasts were increased through the implementation of a preliminary citizen reporting project.

Initial Implementation of Citizen Reporter System

The citizen reporting aspect of this WRTM project was intended to enhance reports by:

- Generating road weather reports at a minimum of every 2 hours for some or all of the roadway segments

- Providing fresher data and better coverage on rural roadways

- Supporting Section 1201 requirements by providing real-time reporting on roads throughout the state

- Actively controlling weather quality reports using staff meteorologists

- Providing quality assurance through a reporter selection process and training

- Providing more information at a fraction of the cost of other alternatives

- Directly improving forecasts through increased frequency (3 hour increments, out 24 hours in the future)

- Indirectly improving forecasts by providing meteorologists with more and better field data

One of Utah DOT's goals was to deploy citizen reporters to provide road weather conditions to help fill gaps in the existing road condition reports and support more timely and accurate forecasts. This initial year of the UDOT citizen reporting program utilized UDOT staff from headquarters, district offices, and the TOC to be the "reporters." The 143 road segments identified statewide for citizen reporter (CR) assignment were characterized as primary, secondary and tertiary in terms of the extent of existing temporal and spatial gaps in road weather data. Sixty-two (62) primary route segments were designated that had minimal to no road weather information from which the meteorologists could base a good forecast, and therefore could benefit the most from citizen reporting. These primary routes were mostly located in the more remote, rural areas that lacked adequate road weather data acquisition coverage. Secondary route segments (56 segments) were designated that had some information, but could use more. Finally, 25 tertiary road segments were included that already provided adequate road weather information to support good forecasting, and citizen reporting was a lower priority in these mostly urban road segments. UDOT developed a smartphone application to facilitate CRs submitting reports on their road weather observations. Fifty-six (56) CRs were trained and assigned specific segments on which they agreed to report. In addition, a reporter was free to report on any other road segment where they might be driving. Of those trained, thirty-one (31) ended up submitting reports.

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Evaluation Findings

This initial citizen reporter system was evaluated to assess its effectiveness and future potential to supplement UDOT's existing systems for gathering and disseminating road weather information. The objectives of the evaluation included measuring the following:

- Success of citizen reporting at filling existing gaps in weather observations along roads in Utah with an emphasis on primary road segments

- Timeliness and accuracy of citizen reports

- How or whether the enhanced weather forecasting and road condition reporting improves internal UDOT operations

- Whether the traveling public finds the enhanced weather information useful and how the information was used during the 2012-2013 winter season

- How or whether traffic patterns can show a public response to road weather forecasts prior to high-impact storms

The evaluation addressed five testable hypotheses, as shown in Table ES-1, along with a summary of the main results associated with each hypothesis:

Table ES-1. Evaluation hypotheses and summary of results.

Hypothesis	Evaluation Results
1: Citizen reports will help fill observation gaps, spatially and temporally	• Of 56 trained CRs, 31 actively submitted reports. • A total of 607 reports were submitted, distributed across 143 road segments. • 54 of the 143 segments had no CRs assigned. • More reports were submitted for tertiary road segments (312) than for primary (180) or secondary (115), though the greatest information gaps exist on the primary segments. • More reports were submitted on weekdays than on weekends, and during the early morning, primarily due to commuter reporting. • An average of 8.5 reports were submitted per day on storm days compared with 2.7 reports on non-storm days.
2: Citizen reports will provide accurate information to UDOT	• CR reports were very accurate (over 99%). • 71% of reports had little or no delay between observation and submittal time; i.e., the data were current. 14% were submitted within an hour of observation, and 7% more than two hours after observation (no longer valid). On storm days, the submittals with no delay rose to 76%. • The average update gap (elapsed time without fresh CR data, not considering other data sources) was 7.5 hrs for all segments receiving at least one report.
3: Internal UDOT operations will benefit from increased road condition reports and forecasts	• CR reports provided increased situational awareness for meteorologists and TOC operators. • CR reports increased confidence in road weather forecasts.

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Hypothesis	Evaluation Results
4: The traveling public will make more informed decisions based on the new information	• 35%-50% of survey respondents said they benefited indirectly by using local media for storm information in support of their travel decisions; 5%-10% used UDOT traffic forecasts directly. UDOT shares information with the media.
5: The traveling public will perceive a benefit from the enhanced information	• 83% to 95% of respondents to two post-storm surveys said they were satisfied with UDOT's road weather forecasts and the traffic app or website. • Two focus group sessions revealed frequent use of the UDOT traffic app during storms; drivers appreciate the real-time, accurate weather information; and, the CR program is viewed as useful and providing accurate information.

Source: Battelle

Based on the findings from the evaluation, the report recommended a variety of ways that UDOT could enhance the benefits of the CR program as it is expanded in the future. These included suggested strategies for CR recruitment, training, and performance monitoring with the objective of enhancing reporting by route segments and time of day which represents the greatest information gaps, and reducing the gaps between observation and report submittal. It was also suggested that the TOC meteorologists document how they use the CR observations to strengthen the case for the value of the program.

Conclusions

The addition of citizen reports will help fill gaps in available road weather data, provide for "fresher" data than have been available in the past, support UDOT's plans to enhance their road weather forecasts, and help meet state and national transportation goals for safety and mobility during weather events. In the longer term this program is expected to raise awareness throughout the state of Utah regarding the challenges to safe driving during adverse weather and the benefits offered by new tools and better information to aid travelers in avoiding or handling potentially dangerous driving conditions. Finally, the lessons from this initial implementation will help UDOT further develop and move this program forward and serve as a valuable model for other state DOTs that seek to implement similar traffic management strategies in bad weather.

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Chapter 1 Introduction

Weather Responsive Traffic Management (WRTM) involves the implementation of traffic advisory, control, and treatment strategies in direct response to or in anticipation of developing roadway and visibility issues that result from deteriorating or forecasted weather conditions. WRTM also includes using weather forecasting to provide proactive advisories and control strategies based on forecasts of weather conditions, and not just the results of those conditions. The Federal Highway Administration's (FHWA) Road Weather Management Program (RWMP) has, as one of its primary focus areas, been encouraging the development and implementation of WRTM strategies. This report specifically addresses a recent implementation of a WRTM strategy in Utah: Road Weather Traveler Information (Wx-TINFO). Background information regarding the larger WRTM Project is first described below.

Background

The impacts of weather on traffic operations are well-documented in literature. Over the past decade, the RWMP has championed the cause of improving traffic operations and safety during weather events. The program's current emphasis is to encourage agencies to be more proactive in the way that they manage traffic operations during weather events. WRTM brings together into a logical framework the various other activities (such as weather information integration, Clarus, traffic analysis, performance measurement, etc.) that the RWMP has been supporting. WRTM is not a single strategy per se but a combination of techniques, tools, and systems that transportation authorities can use for mitigating the impacts of weather on their operations.

WRTM at the core includes a set of actionable strategies that a transportation operator can implement, covering advisory, control and treatment. Supporting the ability to implement these strategies are various important elements of WRTM (see Figure 1-1). These elements include:

- Traffic and Weather Data Collection and Integration – focusing on the integration of appropriate weather and traffic information to enable an agency to make decisions in a more proactive manner.

- Traffic Analysis, Modeling and Simulation – providing the analytical capabilities to assess impacts of weather events on traffic operations, and the tools necessary for a traffic manager to make informed decisions, including information from the other elements.

- Human Factors – addressing the appropriateness of the strategies for message dissemination as well as issues relating to driver behavior in various weather conditions (such as lane changing, gap acceptance and car following).

- Performance Evaluation – determining the benefits of implementing WRTM strategies.

While each of these areas is not new to a transportation agency, the umbrella framework of WRTM brings together all these interlinked pieces to achieve coordinated, proactive, and effective responses to weather events.

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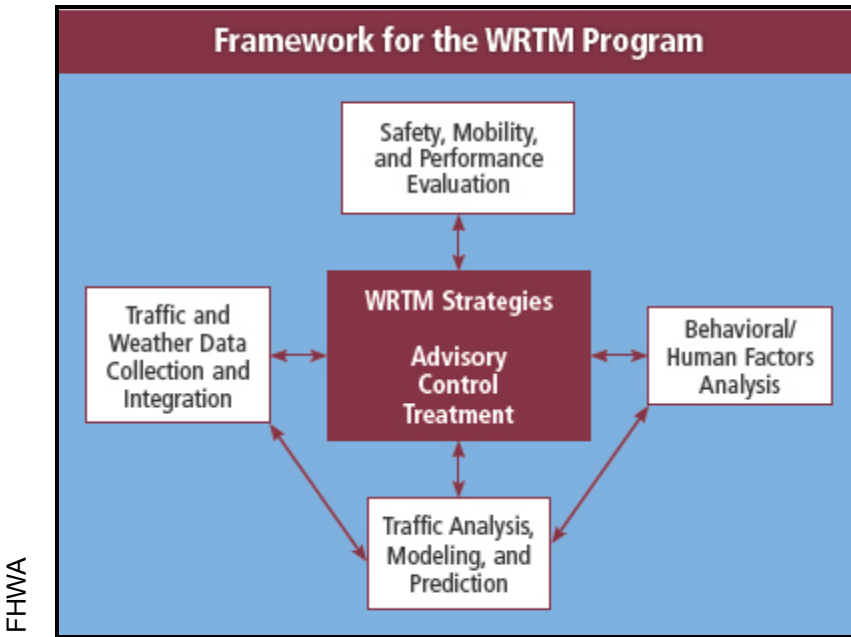
Figure 1-1. Framework for the WRTM Program

Consistent with the framework in Figure 1-1, the RWMP has initiated and completed several activities to develop, research, and document tools for WRTM. The RWMP has prepared guidance documents and research reports that agencies can use to guide the integration of weather information in their traffic operations, analyze the relationships between weather conditions (e.g. precipitation, and visibility) and traffic parameters (e.g. volume, speed, density, driver behavior including lane changing, car-following and gap acceptance), and evaluate the effectiveness of road weather advisory messages.

In 2011, the RWMP initiated a project to document existing strategies for WRTM, identify improvements to the strategies, and develop implementable Concepts of Operations for the improved strategies[1]. The Concepts of Operations were developed using a standard format for the following strategies:

1. Weather Responsive Active Traffic Management – includes vehicle, facility and route control (Wx-ATM)

2. Weather Responsive Traffic Signal Management (Wx-SIG)

3. Weather Responsive Traveler Information – includes both pre-trip and en-route traveler information (Wx-TINFO)

4. Seasonal Weight Restrictions

5. Intra- and Inter-agency Coordination

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[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

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Overall Project Objectives

While the previous study in 2011 identified several WRTM strategies being implemented by State DOTs, in many cases they did not represent the full extent of the WRTM framework as defined in Figure 1-1. The main objective of the overall project was to help implement a WRTM operational capability within the agency that considered all the elements of WRTM.

The overall project focused on the core (the middle box in Figure 1-1) of WRTM helping State DOTs implement strategies based on the proposed Concepts of Operations. Of the five concepts listed, the first three were chosen as candidates to move toward implementation. These three strategies, Wx-ATM, Wx-SIG, and Wx-TINFO, represent concepts with the highest readiness levels and interest from the practitioners.

Not intended as a research effort, the Concepts of Operations were the starting point to help the partner agencies implement a capability that would continue to be used in day-to-day operations. Each implemented concept was intended to achieve the following objectives.

- Use the full extent of available weather and traffic data to support decision-making during adverse weather
- Provide improved advisories, notifications and control capabilities to the implementing agency
- Result in improved performance outcomes relating to safety and mobility during adverse weather.

Implementation Approach

Once the concepts were selected for implementation, a rigorous stakeholder engagement approach was undertaken to identify State DOT partners for implementation. Working within tight budget and schedule constraints, structured interviews were conducted with several State DOTs to ascertain their interest in partnering with RWMP in this project. Partnering implied the following commitments by the agency:

- Implementing a project consistent with the guidelines set forth by the WRTM Concepts of Operations
- Deploying or accomplishing the major milestones of the project by the winter of 2013
- Committing to operate and use the results of the projects as part of daily operations
- Providing a minimum of 20% of the overall cost as local matching funds and resources.

Multiple agencies expressed interest in various concepts and ultimately, two States were identified to partner with RWMP to implement the three concepts. This identification was based on the assessment of readiness of the partners to move ahead with these concepts immediately after the agreement. Oregon DOT was the partner to implement a Weather Responsive Active Traffic Management system and Utah DOT was the partner selected to implement the signal control and traveler information strategies. Both agencies committed more than the required share of funds necessary to implement this project.

Each of these implementations is described in a separate report. This report documents the implementation of the Weather-Responsive Traveler Information Strategy by Utah DOT (UDOT).

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Wx-TINFO Strategy Implementation Overview

UDOT already has one of the most sophisticated Traffic Operations Centers (TOCs) in terms of how they obtain and integrate road weather information in traffic management decisions. On-site meteorologists provide current conditions and road weather forecasts to maintenance dispatchers and traffic operations staff on a regular basis and when inclement weather is imminent. With this level of detailed road weather-related information, they also provide current conditions and forecasts to travelers through their various dissemination approaches (511 phone, UDOT Traffic website (including the new TravelWise alert notification system), UDOT Traffic twitter, UDOT Traffic smartphone application, and other en-route methods – HAR and DMS).

The UDOT Weather Responsive Traveler Information strategy implementation project set out to make significant improvements in the current operations activities in an effort to improve the timeliness and accuracy of the information provided to travelers. Specific objectives were to:

- Increase the frequency of weather forecasts from 6 hour increments, 18 hours in the future (3 forecasts) to 3 hour increments, 24 hours in the future (8 forecasts).

- Provide road weather forecasts to 6 additional state routes of significance (US-191, US-89, US-189, SR-20, SR-210, and SR-190 (this is in addition to the 7 interstates and US highways already receiving public forecasts).

- Develop and implement an initial citizen reporting system. This system will use the current UDOT Traffic smartphone applications to allow citizens to report back to UDOT conditions on their roadways (for the initial system, a separate smartphone citizen reporting app was developed). The initial implementation included UDOT employees only – each reporter was trained on how to record observations and submit reports.

- Make appropriate software changes to manage the additional data and forecasts and disseminate them to travelers using the UDOT Traffic website, 511 phone system, and smartphone applications.

Organization of the Report

The rest of the report describes the Utah DOT traveler information strategy implementation in detail describing the implementation, the operations and the evaluation conducted as part of this effort. The report is organized as follows:

- Chapter 2 describes UDOT's traveler information concept of operations

- Chapter 3 describes the project implementation details

- Chapter 4 describes the evaluation approach

- Chapter 5 provides the results of the evaluation

- Chapter 6 summarizes the conclusions and lessons learned

- Chapter 7 defines the recommendations to FHWA to expand their WRTM implementation efforts

- Appendix A includes the full concept of operations developed for this implementation

- Appendix B includes the complete evaluation plan for this implementation.

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Chapter 2 Wx-TINFO Concept of Operations

UDOT developed a Concept of Operations (ConOps) for their Weather-Responsive Traveler Information System based on the ConOps developed in the FHWA study[1]. The UDOT ConOps is contained in Appendix A. The paragraphs that follow provide a summary of the project and how it was intended to be operated.

Objectives

The primary goal of the Utah DOT WRTM Traveler Information project was to provide both TOC operators and travelers with more accurate and timely road weather and travel impact condition information and forecasts. UDOT provides both current conditions and forecasted information. However, this information is not as timely and accurate as UDOT would prefer it to be due to the rapidly changing weather conditions and in some areas the lack of sufficient road weather data from which to assess current conditions and forecast future conditions for the benefit of both operators and travelers.

In order to achieve this goal, the project objectives were to:

- Increase the frequency of weather forecasts from 6 hour increments, 18 hours in the future (3 forecasts) to 3 hour increments, 24 hours in the future (8 forecasts).

- Provide road weather forecasts to 6 additional state routes of significance (US-191, US-89, US-189, SR-20, SR-210, and SR-190; this is in addition to the 7 interstates and US highways already receiving public forecasts).

- Develop and implement an initial citizen reporting system. This system will use the current UDOT Traffic smartphone applications to allow citizens to report back to UDOT conditions on their roadways (for the initial system, a separate smartphone citizen reporting app was developed). The initial implementation of this system included UDOT employees only – each reporter was trained on how to make reports.

- Make appropriate software changes to manage the additional data and forecasts and disseminate them to travelers using the UDOT Traffic website, 511 phone system, and smartphone applications.

Implementing this project was expected to improve the accuracy and timeliness of weather-related traveler information. The currency and resolution of road weather observations and road weather forecasts were increased. Specifically, the citizen reporting aspect of this project was designed to enhance reports by:

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- Generating road weather reports at a minimum of every 2 hours for some or all of the roadway segments.

- Providing fresher data and better coverage on rural roadways

- Supporting Section 1201 requirements by providing real-time reporting on roads throughout the state

- Actively controlling quality reports using staff meteorologists

- Providing quality assurance through a reporter selection process and training

- Providing more information at a fraction of the cost of other alternatives

- Directly improving forecasts through increased frequency (3 hour increments, out 24 hours in the future)

- Indirectly improving forecasts by providing meteorologists with more and better field data.

Existing UDOT System

UDOT currently has a robust road weather condition and forecasting system that provides information to the traveling public through several dissemination methods. A summary of the related systems and approaches include:

- Meteorologists residing at the UDOT TOC who provide route-specific road weather conditions and forecasts to the traveling public and TOC operations staff.

  - Various weather data sources are aggregated, analyzed, and used to develop the road weather current conditions and forecasts.
  - Current conditions are reported for all state roadways in 143 segments.
  - Forecasts are provided for major routes throughout the state and currently include 6-hour forecasts, 18 hours in the future.
  - In addition to the current conditions and forecasts, periodic briefings are provided to operations staff when inclement weather conditions are anticipated. This information is used to dispatch maintenance resources, post alerts, activate DMS signs, etc.

- Information disseminated to the traveling public through the following methods:

  - UDOT Traffic website
  - UDOT Traffic smartphone applications (iPhone and Android apps)
  - TravelWise push alert notification system
  - 511 traveler information phone system
  - UDOT Twitter feed
  - Dynamic Message Sign (DMS) locations
  - Highway Advisory Radio (HAR) stations

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Relationship to WRTM Strategies

UDOT's current approaches accomplish many of the advisory strategies defined in the general Traveler Information ConOps. This project expands and enhances their ability to provide accurate and timely road weather conditions and forecasts.

Table 2-1 (next page) maps the WRTM Traveler Information concept strategies to the UDOT Wx-TINFO project.

Table 2-1. Mapping of UDOT Wx-TINFO Project to WRTM TINFO strategies defined in the ConOps.

WRTM TINFO Strategies	UDOT Wx-TINFO Project
Collect, aggregate, and synthesize weather information from a number of different sources, including (but not limited to) Road Weather Information/Environmental Sensing Stations, *Clarus*, and both public and private weather information service providers.	UDOT already accomplishes this strategy. **The project adds a new road weather data source with the citizen reporting system.**
Provide route-specific road weather condition forecasts up to 12-hours in the future.	UDOT already accomplishes this strategy. **The project provides road weather forecasts 24 hours into the future in increments of 3 hours.**
Using the forecasted weather conditions as well as current and historical traffic conditions, predict the impacts of weather conditions on traffic operations in a regional network, specifically identifying when and where weather events will create operational deficiencies in the network.	UDOT accomplishes this strategy using contracted meteorologists who reside in the TOC and provide road weather conditions and forecasts to support TOC operations. **The project enhances the information available to the meteorologists who in turn can provide more accurate and timely information.**
Generate appropriate route-specific road weather and traffic forecast messages to be distributed through regional pre-trip traveler information dissemination systems, such as websites, traveler kiosks, etc.	UDOT accomplishes this strategy by disseminating road weather conditions and forecasts to the traveling public through the UDOT Traffic website, 511 phone system and UDOT Traffic smartphone applications. **The project updated the UDOT Traffic website to accommodate the higher frequency forecasted information and on additional US and State routes.**
Generate appropriate route-specific road weather and traffic forecast messages to be distributed through regional en-route traveler information dissemination systems, such as dynamic message signs (DMS), highway advisory radio (HAR), 511 and others.	UDOT accomplishes this strategy through their use of DMS, HAR stations, 511 phone system and UDOT Traffic smartphone applications. **The project updated the smartphone applications and 511 phone system to provide new information.**
Generate appropriate route-specific road weather and traffic forecast messages to be distributed through regional non-traditional traveler information dissemination systems, such as social networking systems, text alerts, and others.	UDOT accomplishes this strategy through their use of the UDOT Traffic smartphone applications and Twitter feeds. **The project developed a new citizen reporting application (tied to their smartphone application) to receive information directly from a select group of trained citizen reporters. The intention is to expand this to the public as a future enhancement.**

Source: Battelle

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Implementation Components Summary

The UDOT Wx-TINFO System implementation project consists of the following components:

- Additional road weather meteorological staff to provide more frequent forecasts and forecasts for additional roadways

- Trained citizen reporter volunteers, recruited among UDOT staff for initial implementation

- New system data management software developed to address more frequent forecasts on existing and new roadways, incoming citizen reports, and flagging of inaccurate reports

- New smartphone application software for iPhone and Android developed to support citizen reporting

- Expanded traveler information dissemination software to display more frequent forecasts and forecasts for additional roadways on UDOT's Traffic website, 511 phone system and Traffic applications for iPhone and Android smartphones

A more detailed description of these components and activities conducted to implement the project is presented in the next section.

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Chapter 3 Project Implementation

Site Selection

Choosing the correct site for Wx-TINFO implementation was critical to the success of the project. The site was required to demonstrate it was ready to implement some or all aspects of the WRTM Traveler Information concept of operations, express a strong interest in participating, and meet several programmatic constraints (schedule and budget). The FHWA contractor established a list of candidate states that may be both interested and capable of meeting the criteria for involvement. The following candidate states were contacted:

- California
- Idaho
- Kansas City – Scout
- Nevada
- Oregon

- South Dakota
- Utah
- Washington
- Wyoming

Criteria

The goal of the project was to develop and implement a Wx-TINFO system in a state, large region, or primary corridor to operationalize a WRTM Traveler Information strategy and concept of operations. The project also included system evaluation to document the effectiveness of the implementation. The criteria used to select the most appropriate implementation site included the following:

1. Currently operating a statewide/regional traveler information system that values the use of road weather information
2. Expressed interest in significantly expanding the use of road weather information to improve dissemination of forecasted road weather information, determining the impacts of weather on travel conditions, and incorporating the expanded information in traffic management operations. Specific technical capability desired included:
   a) Currently collecting, aggregating, and synthesizing weather information from a number of different sources, along with:
   b) Currently have (or have the ability to add) systems to support the preparation of route-specific road weather condition forecasts
   c) Ability to generate appropriate route-specific road weather and traffic forecast messages for different target groups through different media
3. Ability to secure matching resources, in cash or kind and available within the project timeframe
4. Ability to commit staff, time, and resources to successfully accomplish the project
5. Ability to meet tight project schedule – project implemented and evaluated during winter of 2012-2013.

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Results

Although all of the candidate sites were interested in moving toward implementing some form of the Wx-TINFO strategy and concept of operations; only a few had the infrastructure in place, were prepared to implement a project in the near term, had the resources to support such a project, and could meet the very aggressive schedule. Ultimately, FHWA selected Utah DOT to participate in the project. The primary reasons for this selection included:

- ✓ Extensive infrastructure in-place to implement the project
- ✓ Project concept and management approval obtained – expressed strong interest
- ✓ Available resources committed to the project
- ✓ Commitment to meeting the aggressive schedule
- ✓ Determination that UDOT's completion of this project would provide guidance and demonstrate the benefits of Wx-TINFO to other agencies in the US.

UDOT Project Implementation

The UDOT Wx-TINFO project was accomplished within tight schedule. The project was initiated in September 2012 and evaluated over the 2012-2013 winter period from January through April, 2013. This required that all system development activities be completed by December 2012 (a 4 month period). UDOT met the schedule with all the planned system capabilities operational by January 1, 2013. A brief explanation of each major project component is provided below.

Additional Meteorological Staff

In order to meet the project goal of providing more frequent road weather forecasts and providing forecasts for six additional roadways in the state, extra staff was required. UDOT acquires their meteorological staff (that reside in the TOC) through a contract with Northwest WeatherNet. They worked together to hire two new staff members to support the anticipated increased data management and forecasting requirements. The Traveler Information Meteorologists (TI Mets) focus their efforts on providing accurate and timely road weather reports, especially during storm events, for their operational and maintenance personnel and the traveling public. Previously, traveler information could not be provided as frequently or with as much detail as UDOT desired.

The costs associated with this activity were paid by UDOT state funding, not FHWA funding. UDOT plans to continue this level of meteorological staff support in future years.

Recruited and Trained Citizen Reporters

A major project component was the use of citizen reporters to provide road weather conditions to help fill gaps in the existing road condition reports and support more timely and accurate forecasts. This initial year of the UDOT citizen reporting program utilized UDOT staff from headquarters, district offices, and the TOC to be the "reporters." The 143 road segments statewide were characterized as primary, secondary and tertiary in terms of the extent of existing temporal and spatial gaps in road weather data. Sixty-two (62) primary route segments were designated that had minimal to no road weather information from which the meteorologists could base a good forecast, and therefore could benefit the most from citizen reporting. These primary routes were mostly located in the more remote, rural areas that lacked adequate road weather data acquisition coverage. Secondary route segments

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(56 segments) were designated that had some information, but could use more. Finally, 25 tertiary road segments were included that already provided adequate road weather information to support good forecasting, and citizen reporting was a lower priority in these mostly urban road segments.

UDOT put forth an extensive effort to recruit and train citizen reporters by asking UDOT staff to volunteer. A comprehensive training program was prepared and used to train the volunteers. UDOT conducted numerous in-person training sessions with those interested and willing to report. The training materials consisted of a comprehensive 36-slide PowerPoint presentation that described how the tool worked and how to report location, time, and road weather road conditions. It included specific pictures of types of road weather conditions to ensure consistent reports by the reporting volunteers. Fifty-six (56) citizen reporters were trained and assigned specific segments on which they agreed to report. In addition, a reporter was free to report on any other road segment where they might be driving. Of those trained, thirty-one (31) ended up submitting reports. The evaluation (Chapter 5) describes in greater detail the effectiveness of the reporters. The lessons learned from this initial year that can be used to guide an expansion of the program in future years are provided in Chapter 6.

Developed Software to Manage New Data Elements

Several new data management software elements were developed and implemented in the early stages of the project. The software included:

- Forecast database expansion – to accommodate the more frequent road weather forecasts and forecasts for additional roadways. The existing software to house, maintain, and manage these data was adjusted to handle the expanded database requirements.

- Road weather condition database expansion – to accommodate the addition of the citizen reports. Currently the road weather condition database receives the reports provided twice daily for each segment by the UDOT plow drivers. The software was expanded to include the citizen reports and allow the TI Mets to review/accept the citizen reports. Additionally, the software required alterations to interact with the traveler information dissemination software.

- Log "tagged" citizen reports – to track citizen reports that are considered not accurate or not appropriate to the conditions. This was a requirement of the project evaluation and is reported later in this document. This approach was used to "tag" individual reporters who were not performing according to the project guidelines and prevent inaccurate or inconsistent reports from being included in the traveler information integration and dissemination system.

Developed Smartphone Application Software for Citizen Reporting

Currently, UDOT's Traffic smartphone applications provide traveler information (one-way) similar to that on the UDOT Traffic webpage. They support systems using both iPhone and Android operating systems. New smartphone software was developed, tested, and implemented for both operating systems to allow citizen reporters the ability to make road weather reports for any of the 143 roadway segments statewide. These new smartphone applications were only made available to trained citizen reporters recruited for initial project implementation. The resulting reports were directed into the UDOT road weather condition database for review by the TI Mets and inclusion in the traveler

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information dissemination tools. The Citizen Reporting application is separate from the UDOT Traffic application and there are no plans to combine them.

The UDOT citizen reporting smartphone app was developed to be easy to use with drop down menus describing location, time, and road weather conditions. Figure 3-1 illustrates the citizen reporting smartphone app screen shot examples.

Utah DOT.

Figure 3-1. Citizen reporting Smartphone app screen examples.

Expanded Traveler Information Dissemination Software

UDOT's primary traveler information dissemination methods include the UDOT Traffic website, 511 phone system, and UDOT Traffic smartphone applications (iPhone and Android operations systems). Software to support each of these methods to provide traveler information to the public was developed, tested and implemented to accommodate the new traveler information, including:

- Higher frequency forecasts (every 3 hours out 24 hours in the future)
- Additional roadways receiving forecasts

Figure 3-2 illustrates UDOT's Traffic website that provides road weather forecasts by road segment every 3 hours – out 24 hours in the future. The information for each segment includes both weather condition as well as traveler impact forecasts.

These project components were implemented and evaluated during the 2012-2013 winter season. Several storm events were recorded during this period. The evaluation of the effectiveness and lessons learned are described in the next three Chapters of this report.

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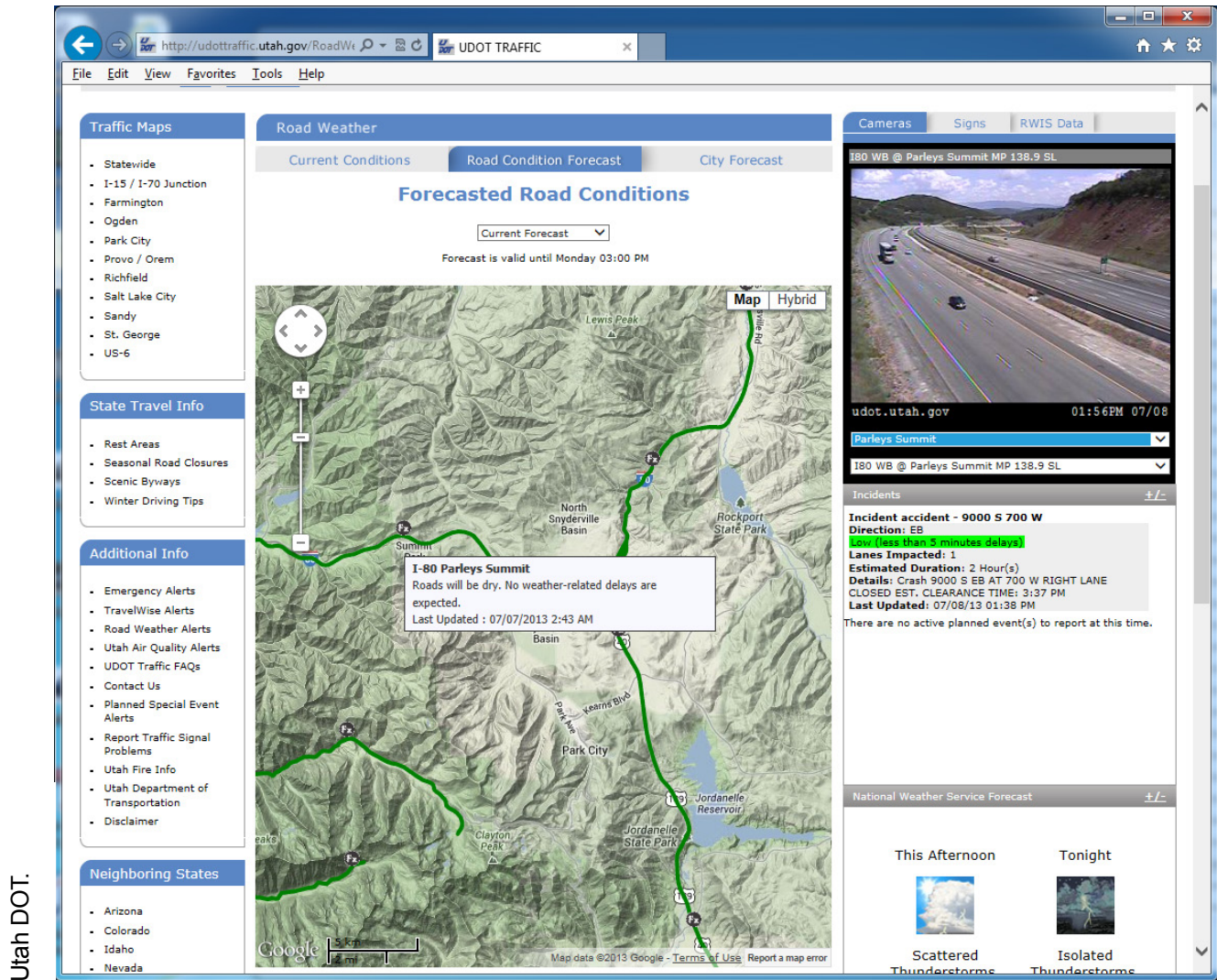
Figure 3-2. UDOT Traffic Website Illustrating Road Weather Forecasts

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Consideration for Future Expansion

UDOT is planning to continue growing the citizen reporting program in the near future. Currently, the following plans to expand the project activities are being considered:

- Utah Highway Patrol officers and dispatchers, members of the Utah Trucking Association, and additional UDOT employees will be recruited and trained to be reporters for the upcoming winter season.
- Additionally, the citizen reporter program will be opened to the public.
- An on-line training component will be available for those persons not able to attend in-person training.
- The long term goal of 800-1000 trained reporters to cover all roadway segments throughout the state will be pursued.
- Logic is being developed to weigh incoming reports from various sources to assist in determining the most appropriate segment condition indicator (red, yellow, green).
- Strong, supportive relationships between UDOT Divisions will continued to be fostered. Some changes to the system applications will be considered:

  - Plow driver inputs will be separated from citizen reports to be able to internally distinguish contributions from both groups. An internal version of the smartphone citizen reporting app for the plow drivers will be used to submit their reports which will provide additional functionality for the drivers. The public will not see the distinction.

The additional information provided through the expanded citizen reporting program will be collected, processed, and provided to the traveling public using the database management tools and traveler information dissemination software developed as part of this project.

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Chapter 4 Evaluation Approach

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

The objectives of the project evaluation include measuring the following:

- Success of citizen reporting at filling existing gaps in weather observations along roads in Utah with an emphasis on primary road segments
- Timeliness and accuracy of citizen reports
- How or whether the enhanced weather forecasting and road condition reporting improves internal UDOT operations
- Whether the traveling public finds the enhanced weather information useful and how the information was used during the 2012/13 winter season
- How or whether traffic patterns can show a public response to road weather forecasts prior to high-impact storms

Additionally, the evaluation was conducted primarily to help guide future program development as it evolves in the coming years. This winter season of 2012/13 is the first year of UDOT's citizen reporting implementation, and the evaluation will help to guide the training and distribution of reporters (number and location) in following seasons.

The Evaluation Plan defined five specific hypotheses to be tested during the evaluation phase of the project. The hypotheses and expected results include:

Hypothesis 1: Citizen reports will help to fill observation gaps, spatially and temporally

- Citizen reports will contribute to the UDOT goal of an updated road condition observation every 2 hours for all roadway segments, especially during inclement weather and in priority segments
- Reporter performance (reports submitted on time) will be acceptable and supportive to meteorologists

Hypothesis 2: Citizen reports will provide accurate information to UDOT

- Citizen reporters will provide accurate information and few will be identified as inaccurate or unreliable

Hypothesis 3: Internal UDOT operations will benefit from increased road condition reports and forecasts

- Citizen reports will improve meteorologists ability to provide forecasts
- Traffic operators will use the enhanced current and forecast conditions to be more aware and post DMS messages

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- Maintenance dispatchers will use the enhanced current and forecast conditions to more efficiently utilize field resources
- Other UDOT groups will use the enhanced current and forecast conditions to better perform their job duties

Hypothesis 4: The traveling public will make more informed decisions based on the new information

- The traveling public will utilize the enhance road weather information prior to the event to consider changes in their travel behavior (delay or advance trip, cancel trip, change route or mode, be more prepared, etc.)
- The traveling public will increase their use of the information (over prior year)

Hypothesis 5: The traveling public will perceive a benefit from the enhanced information

- Traveling public satisfaction will increase with the UDOT traveler information
- Public comments will improve regarding UDOT traveler information and systems (increased positive, decreased negative comments)
- Website and smartphone application usage will increase this season (over prior year)

Associated with each of these hypotheses, the Evaluation Plan defines specific measures of effectiveness, data requirements, and expected analyses to be conducted. These details are summarized in Table 4-1.

The next chapter describes the results of implementing this evaluation approach using the data available during the 2012-2013 winter season.

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Table 4-1. UDOT WRTM Traveler Information Strategy Implementation Evaluation Plan Summary.

Hypothesis	Measures of Effectiveness	Data Needed	Analysis
1 Citizen reports will help to fill observational gaps, spatially and temporally.	Outputs: a. Citizen reporting added to road segments in need of observation b. Time delay between observing road conditions and submitting a report (ob-submit delay) c. Time difference between report (observation) updates (update time gap) d. Temporal nature of reports per segment e. Individual reporter performance	a. TATS segments targeted for citizen reporting in order to fill gaps in observation; Segments covered by assigned citizen reporters b. For each report, observation time and submission time c. For each road segment, report observation times d. Number of citizen reporters assigned to each segment e. Timestamp of reports for each reporter	a. % targeted segments covered by assigned citizen reporters b. Calculate delay between observation and submission times; proportion of ob-submit delays in various interval categories c. Calculate time gap between report updates per segment; proportion of update gaps in various interval categories d. Per segment: # reporters, average ob-submit delay, update gap distribution e. Per reporter: assigned segments, frequency of reporting per day, usual time of reporting
2 Citizen reporters will provide accurate information to UDOT.	Outputs: a. Citizen reports flagged as inaccurate and removed by TI meteorologist b. Enrolled citizen reporters flagged as unreliable	a. Large sample size of incoming citizen reports, QC'd in realtime; tally of inaccuracies found; nature of inaccuracies b. TI manager should keep a log of reporters warned or removed from program	a. Of all incoming citizen reports, fraction flagged as inaccurate; log nature of inaccuracies b. Number citizen reporters warned or cut from reporting program
3 Internal UDOT operations will benefit from increased road condition reports and forecasts.	Outputs: UDOT personnel access to higher resolution road condition and forecast updates. Outcomes: a. Improved traffic operator situational awareness for performing job duties (e.g., posting VMS) b. Improved meteorologists' ability to produce and verify forecasts c. TMD managers making well-informed decisions and learning from post-storm reviews d. Other UDOT groups using information to improve performance	a, b, c. Survey responses from operators, forecasters, managers d. Feedback from managers in other UDOT divisions	- Frequency personnel refer to weather forecast/road condition information on UDOT Traffc and for what purposes - Whether 2012/13 information was helpful/more helpful than in previous years - Open-ended responses of opinions and examples of how information was used to improve job performance - Examples from other UDOT Divisions on whether or how they used the information

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Table 4-1. UDOT WRTM Traveler Information Strategy Implementation Evaluation Plan Summary (Continued)

	Hypothesis	Measures of Effectiveness	Data Needed	Analysis
4	The traveling public will make more informed decisions based on the new information.	Outputs: Traveler decision-making before and during storms Outcomes: a. Relative to non-storm day, more traffic before or after storms; travelers completing trips prior to storms or delaying travel until after storms b. Increased public usage of road weather information prior to event. c. Changes in travel behavior (delay trip, cancel trip, change route or mode, be more prepared, etc.)	a. Traffic volume or vehicle miles traveled data before, during, after storm events (PeMS) b. Page views of road weather page at 20-min intervals, restricted to before and during and event c. Survey or focus group	a. Plot traffic volume or vehicle miles traveled through duration of an event; include prior day if daylong event; compare to travel on same day(s) of week in prior/non-storm years b. Plot page views before & through event on same chart as (a) c. Survey or focus group assessing public's decision-making given their access to enhanced weather information. - users changing departure time, route choice, mode of transport as a result of information - users making pre-trip preparations in response to information - users more likely to monitor weather conditions vs. previous seasons
5	The traveling public will perceive a benefit from the enhanced information.	Outcomes: a. Traveler awareness of and satisfaction with UDOT Traffic weather forecast information will increase b. Increase in positive, decrease in negative public comments on weather info c. Increase in usage of road weather information on website (road weather page, RWP; road weather alert, RWA) d. Increase in UDOT Traffic app downloads and usage	a. NWS/UDOT/UofU survey results b. 511, app, email feedback logs from winters 2010/11, 2011/12 and 2012/13, as available; weather-related marked positive or negative c. Page views of RWP & RWA, from 2011/12 and 2012/13 # storm days d. App downloads, page views # storm days	a. External effort to this evaluation, survey will find out: % SLC drivers using UDOT's information and other sources of information; % satisfied with UDOT Traffic info and with other sources of info b. % occurrence of negative/positive weather-related 511, app, email user comments from 2010/11, 2011/12 and compare to 2012/13 c. All data normalized by storminess (# storm days) Change in total (normalized) RWP & RWA usage from 2011/12 to 2012/13; rate of change in usage per month; average monthly usage over season and change from 2011/12 to 2012/13 d. % increase of app downloads (cumulative) from 2011/12 to 2012/13; trend of downloads over 2012/13 season Change in total (normalized by storm days) usage from 2011/12 to 2012/13; rate of change in usage per month; average monthly usage over season and change from 2011/12 to 2012/13

Source: Utah DOT

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Chapter 5 Evaluation Results

Background

The transmission of road weather information is the foundation of the citizen reporting and enhanced forecasting components of the UDOT WRTM Traveler Information Program. Figure 5-1 illustrates the pathways along which road weather information in Utah ultimately reaches its users: maintenance and traffic operations personnel and the traveling public. Part (a) of the two-part diagram illustrates that weather data are used by UDOT meteorologists to formulate road weather travel forecasts for the public and operational forecasts for UDOT personnel. Path A shows that UDOT Plow Operators input weather observations through the Travel Advisory Telephone System (TATS). TATS has been operational at UDOT for nearly two decades, and reports are entered at least twice daily. Path B illustrates incoming reports from travelers assigned as citizen reporters via the Citizen Reporting smartphone application (app) developed November 2012. Through Path C, these human-derived reports and instrumentation-derived data (from Road Weather Information Systems, radar and traffic cameras) are passed on to a team of meteorologists in the Traffic Operations Center (TOC). The meteorologists use current conditions and weather models to derive two types of forecasts (Path D). Operational road weather forecasts are transmitted to UDOT personnel (Path E) via email, an internal weather website and an internal version of the UDOT Traffic smartphone app. The public receives road weather forecasts (specifically relaying expected travel impacts, Path F) via the 511 phone system, UDOT Twitter feed, UDOT Traffic website and the public-facing version of the UDOT Traffic app. These are the travel forecasts that were enhanced for the 2012/13 winter season, and now extend 24 hours into the future in 3-hour increments, and cover 13 significant routes across the state. The Concept of Operations in Appendix A contains more details.

Current weather conditions are also available directly to UDOT personnel and the traveling public via 511 and the UDOT Traffic website and smartphone app (Figure 5-1b). Weather radar is constantly displayed in the TOC for the traffic operators, and it is made available to plow crews and the public via the National Weather Service website, which links from UDOT's websites. It is important to note that during the initial season of the project, citizen reports were sent directly to the TOC Meteorologists who were charged with quality controlling the incoming reports and reposting them publicly. The Traveler Information Meteorolgoists (TI Mets, who reside opposite the Operational Mets in the Weather Office) used weather observation field devices to ascertain current conditions and maintain a 2-hourly update for all routes throughout the state. TATS reports were also still going to the public. Therefore, what the plublic saw was the same current conditions display from prior years, but with updated information at least every 2 hours, informed by the new information derived from citizen reports. In future seasons, TI Mets will continue to quality control incoming citizen reports, even as the reports are released directly to the public, and the Mets strive to ensure 2-hourly updates are maintained on all routes throughout the state.

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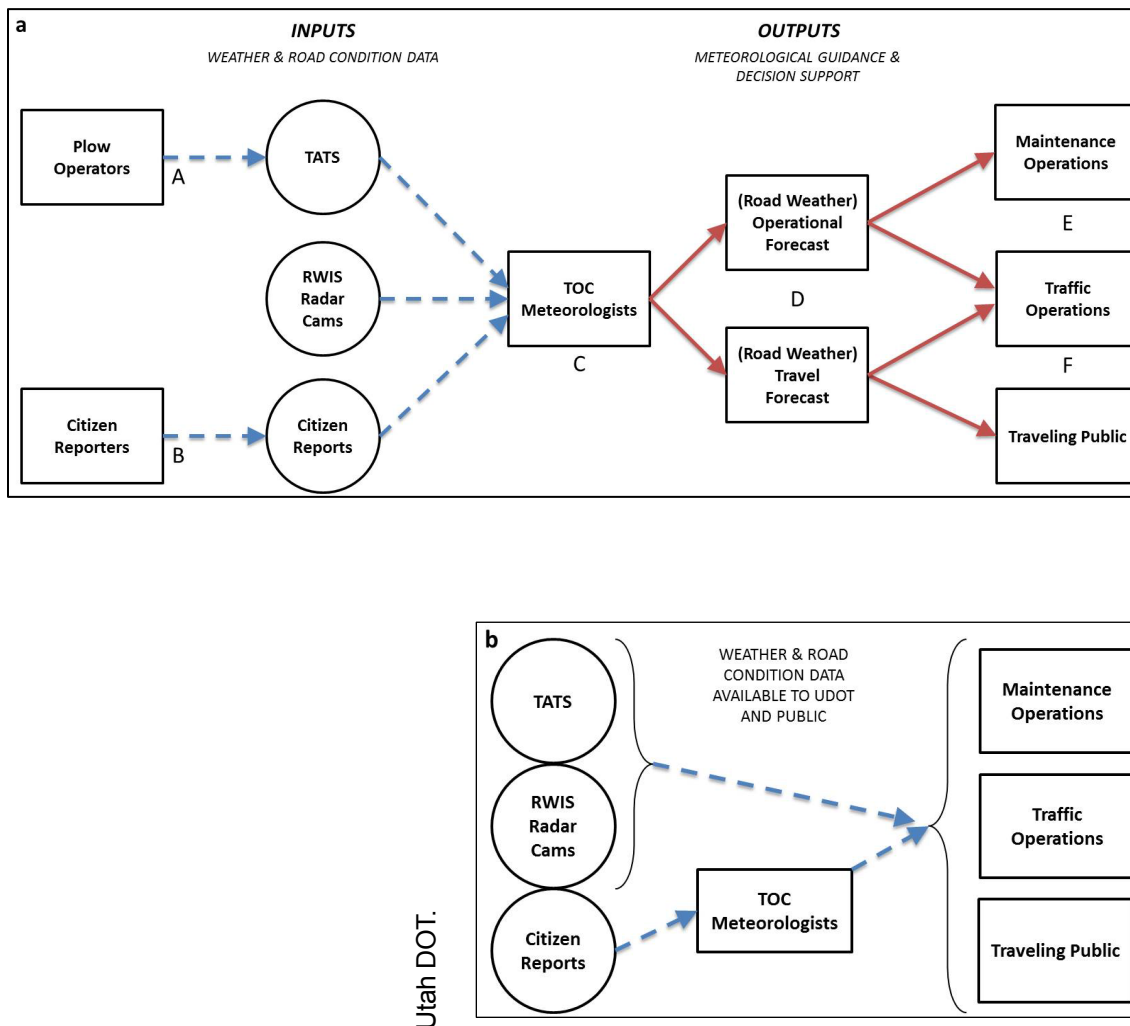
Figure 5-1. Diagrams showing weather information flow. (a) Field data are collected by UDOT personnel (A), motorists (B) and sensors, and are transmitted to UDOT meteorologists (C), who produce operational forecasts (D), which go to UDOT personnel (E) and motorists (F). (b) Field data of current conditions are available directly to UDOT personnel and public motorists; however, citizen reports were not available publicly during the initial season.

The State roadways in Utah are comprised of 143 UDOT-defined segments based on geographic and DOT maintenance boundaries. RWIS, cameras and radar coverage remotely observe weather conditions on many of these segments, but not all segments are created equal in terms of adequate observation. Because of differences in weather observation capabilities and information gaps on various segments throughout the state, citizen reporting is targeted for some routes more than others. Therefore, each route segment was prioritized for citizen reporting by ranking the current level of observation technology present on each. A primary segment was one with minimal to no road weather observation resulting in significant gaps in road weather data, that therefore could benefit the most from citizen reporting; a secondary segment had limited or isolated weather observation; and tertiary segments already had representative coverage of RWIS, cameras and radar, and were less in need of citizen reporting (see maps in Figure 5-2). While this ranking system primarily considers differences in the spatial distribution of observation, there are also differences in temporal distribution

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among observation type. For example, there are many hours between plow driver reports (entered around 7:00 AM and 3:00 PM) and most camera locations do not have nighttime visibility. Radar coverage is also incomplete, with extensive breaks in radar signal through the central and mountainous portions of the state. Overall, rural road segments experience substantially less observational coverage compared with urban segments, and as a result rural segments tend to be designated as primary or secondary and urban segments as tertiary.

Because of micro-climatic variations in weather in complex terrain, many of the road segments in Utah experience a change in weather conditions across their length. One extreme example is State Route 12, in southern Utah. Over its more than 100 miles in length, this singular segment winds through mountains and canyons, and has multiple summits and valleys. It ranges in elevation from 5200 ft to over 9,600 ft, and often experiences degrees of hazardous weather across its length. Because travelers planning to take a given route should be prepared to encounter any hazardous conditions that may exist, citizens reporting on segments with variability in terrain and weather are trained to report the worst conditions on the route.

Of the two portions of the WRTM project – citizen reporting and travel forecast enhancements – the citizen reporting portion introduced the most significant change to current operations. Therefore, most of the evaluation focuses on citizen reporting, including: reporter accuracy, timeliness and distribution, and the lessons learned from the initial season. These measures were addressed in Hypotheses 1 and 2 described in the Evaluation Plan (See Appendix B). Hypothesis 3 addressed the benefits experienced by internal operations as a result of the program. The benefits experienced by the public as a result of the enhanced travel forecast were the goals of Hypotheses 4 and 5.

The evaluation results follow below, but it is particularly important to note that a limited number of reporters and other project implementation constraints prevented as much quantitative analyses as originally planned. In fact, the evaluation results will only focus on Hypotheses 1 – 4. Nevertheless, several important lessons learned that will support future program expansion are documented.

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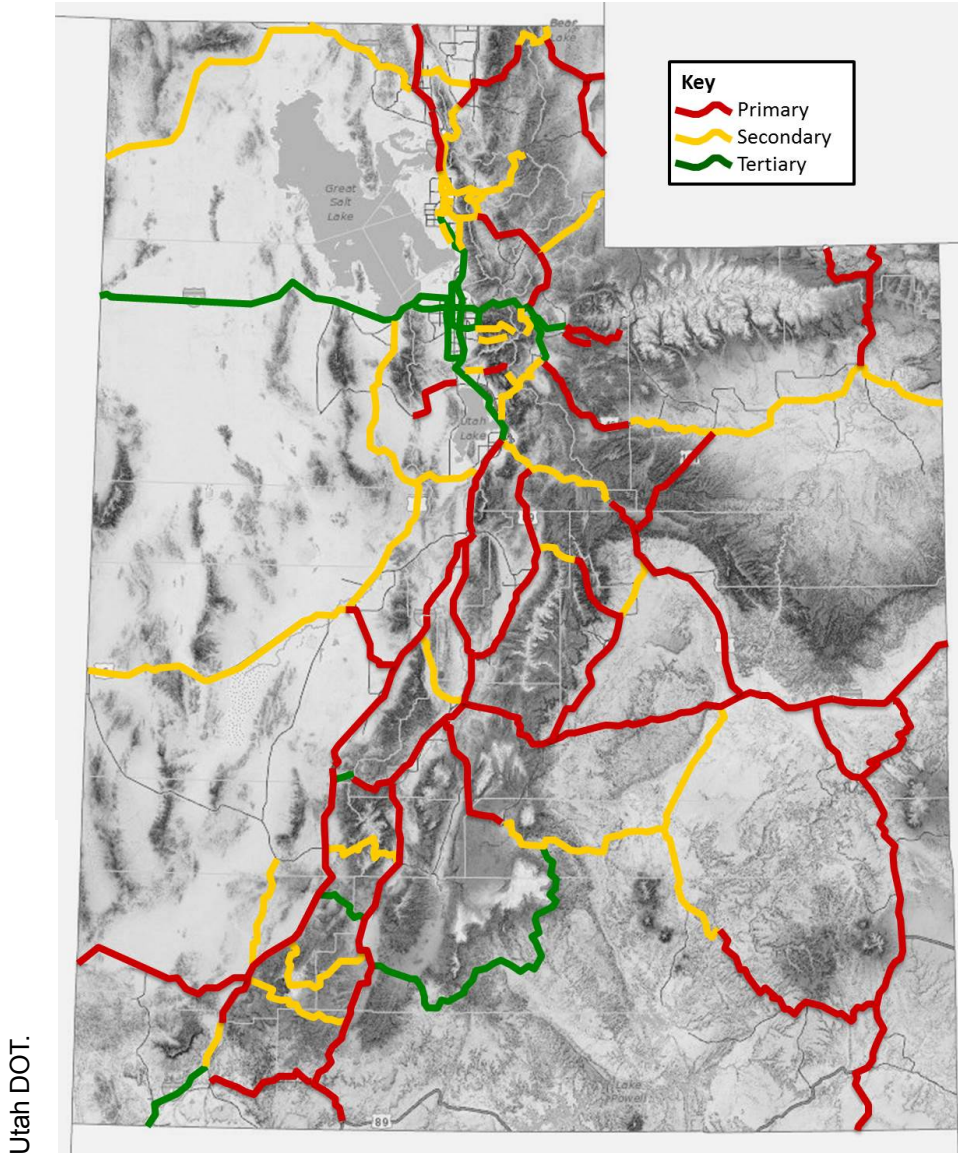
Figure 5-2. Map of Utah showing primary (red), secondary (yellow) and tertiary (green) route segments.

Descriptive Results

UDOT employees were recruited and trained as citizen reporters (CRs, hereafter) to provide a controlled population during the initial season of the program. Traffic operations program managers, maintenance managers, plow drivers, port of entry employees across the state, and other leadership were among the initial recruits. Training sessions were held in-person or via phone conference. By the end of the season, 56 CRs had been trained and assigned segments, though 31 actually became *active*, having begun to report on their assigned segments. That is, not all trained CRs submitted observation reports, and, as will be shown, there is a large disparity between reporting frequency per CR, as well. Of those who did not become active by season's end, a few encountered issues with the

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citizen reporting smartphone app technology. It is assumed that others lost interest or forgot to report. It is therefore recommended that the manager of the citizen reporters maintains frequent contact with and solicits feedback from the reporters in order to keep them engaged and to help troubleshoot any problems encountered.

Segment and CR statistics are summarized by primary, secondary, tertiary and all route segments in Table 5-1 (the "All" row is italicized for clarity). The number of segments assigned to each designation is listed in column 1 and the total number of *valid* reports that were submitted for each is in column 2. A valid report is one that was entered in a timely enough manner to be accepted and used, as will be discussed further in the Citizen Reporting Assessment subsection. Column 3 shows the number of *active* CRs who contributed to the reports in column 2, although there were around twice as many CRs *assigned* to these segments (column 4). Primary, secondary and tertiary are abbreviated P, S and T in the tables below. Also note that CRs are assigned to segments that they frequently travel, but they can report on any roadway segment in the state. Columns 5 and 6 list the number of segments of each designation (primary, secondary or tertiary) that had at least 1 active and at least 1 assigned CR, respectively, by season's end.

Table 5-1. Segment and CR statistics as of the end of the reporting season (56 trained and 31 active CRs).

	1	2	3	4	5	6	7
	# Segments	Total Valid Reports	Of 31 active CRs, how many were active on P, S, T?	Of 56 trained CRs, how many were assigned to P, S, T?	Segments with 1+ active CR	Segments with 1+ assigned CR	Average assigned CRs per segment
Primary	62	180	12	27	25	28	1.0
Secondary	56	115	22	41	28	36	1.9
Tertiary	25	312	24	41	22	20	5.3
All	*143*	*607*			*75*	*84*	*2.1*

Source: Utah DOT

The final metric in column 7, assigned CRs per segment, was used to assess progress toward UDOT's goal of 8-10 reporters per segment. However, the values in column 7 are averages, and there was a range of assigned CR totals. Fifty-four of the 143 total route segments had 0 assigned CRs, and the greatest numbers of assigned CRs per primary, secondary and tertiary segments were 10, 9 and 18, respectively. There were also far fewer reports submitted for rural routes vs. urban, even though those rural routes tended to be the primary routes.

Notice that there are approximately 2 to 2.5 times the number of reports on tertiary segments than there are on primary and secondary, despite there being less than half the number of tertiary segments compared with the other two. Furthermore, there are a similar number of active CRs on secondary and tertiary segments. UDOT was not able to solicit and train as many reporters as desired to the aggressive project schedule. Additionally, some volunteers that did not drive rural segments asked if they could be a reporter, and rather than turn them away because they did not drive rural routes, they were accepted into the program. The apparent contradiction described above

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can likely be explained by the reporting habits of various CRs: (1) the CRs assigned to tertiary segments, submitted 2-3 times more reports on their routes versus the CRs assigned to secondary segments; (2) the CRs assigned to tertiary segments were recruited and trained closer to the start of the season, allowing for more reports by season's end; and (3) as shown in columns 5 and 6, there were more tertiary segments that received reports than had CRs assigned to them. The last point (3) suggests that because tertiary segments were often located in areas with greater daily travel, if CRs happened to be traveling through the metro area, they would submit a report, even though the route was not one of their usual, assigned segments. In the next section (Citizen Reporting Assessment), a designation will be made between urban and rural segments, the former having received far more reports than the latter (not shown in Table 5-1).

The first point above (1), that reporters on tertiary segments reported more often, may reflect the fact that a number of these CRs worked in the TOC, and therefore were more involved and familiar with the program. During this initial season, while the focus of recruiting was on primary segments, the nature of the UDOT employee recruitment yielded many reporters in the Wasatch Front area. As the program expands to other agencies and to the public, it is expected that the fraction of CRs assigned to primary routes will increase. Traveler Information personnel in the TOC should maintain frequent communication with all reporters to keep those more removed from the TOC engaged and informed.

Figure 5-3 shows the temporal distribution of reports by day of week and time of day. In general, there were more reports during the work week and during the daytime hours. This distribution follows what would be expected from the UDOT employees that were CRs this season. Most reported during their commutes or when they were doing work in the field. There is a significant spike in reporting during the morning hours as personnel were commuting to work, but reports drop through the day. In many circumstances CRs would remember to report once they got to work, but would forget to report at the end of the day. UDOT could consider methods to remind CRs to submit a report when their trip is completed, for example, by including user-defined reminders in the citizen reporting app.

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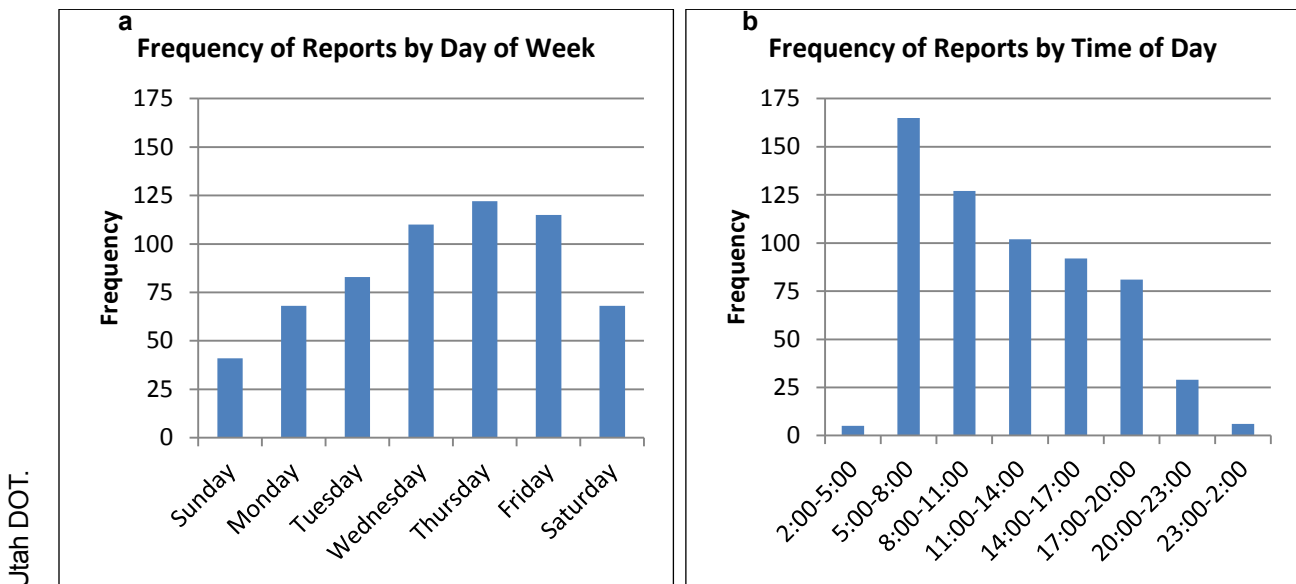
Figure 5-3. Frequency of reporting by (a) day of week and (b) time of day for all reports from the 2012-2013 season, out of the 607 valid reports received.

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A storm day is defined as any day with adverse weather occurring across a portion of the state and associated with a large-scale storm system. Each storm day is identified and logged by the UDOT meteorologists. Figure 5-4 shows reports per day (red columns), and the blue columns represent storm days; the data are listed in Table 5-2. At an average of 8.5 reports per storm day and 2.7 reports per non-storm day, CRs reported over 3 times more often on storm than non-storm days, even with relatively fewer storm days.
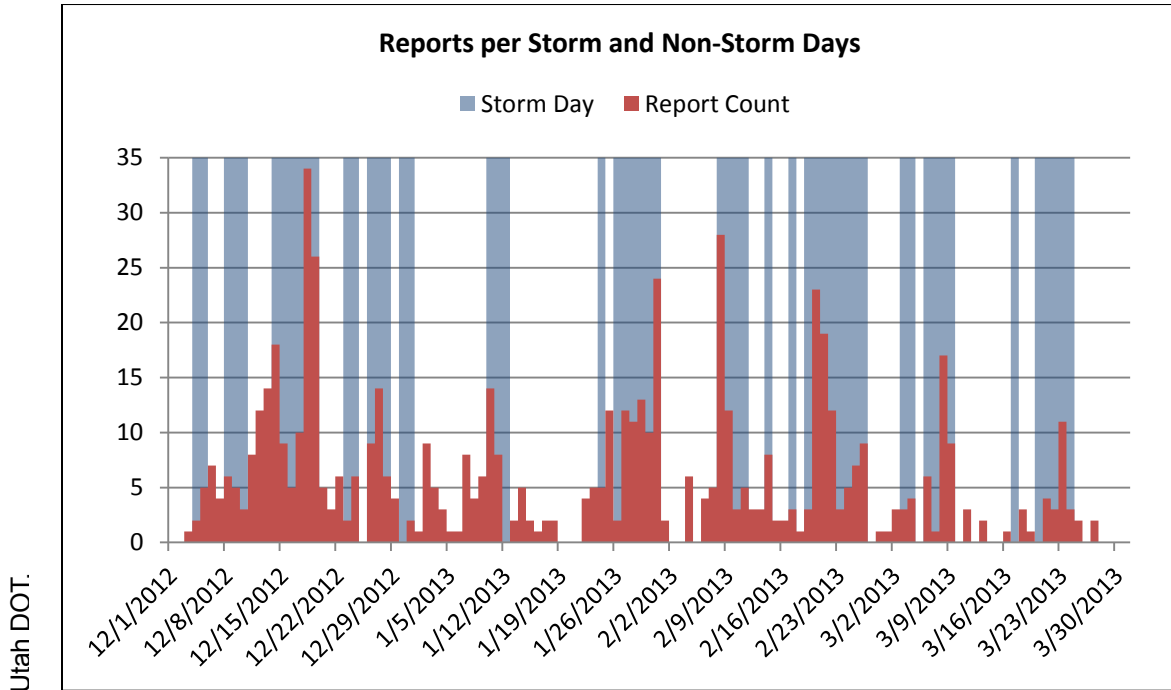
Figure 5-4. Count of reports (red) submitted on storm days (blue) and non-storm days (white).

Table 5-2. Storm day and non-storm day reporting statistics.

	# Days	Report Submissions	Avg. Rep per Day
Storm Days	54	466	8.5
Non-Storm Days	67	185	2.7

Source: Utah DOT

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It is critical for reports to remain updated during storm days; however, UDOT will continue to encourage reporters to submit on non-storm days, as well. Updated clear road reports are important for traveler information. A lack of road condition updates should not be interpreted by travelers as an "all-clear," since, in Utah's complex terrain, micro-climates can cause isolated areas of hazardous weather. Furthermore, consistent reporting keeps CRs engaged during periods of dry weather during the winter season.

Data Analysis

The results in this section follow the analyses outlined in the Evaluation Plan. However, data constraints faced during the season necessitated some alteration of the methods proposed in the original plan. Therefore, while the following subsections describe the results obtained from the assessments that were possible, lessons learned and recommendations for going forward are an important component of the results and are also included. The three subsections below are: (1) Citizen Reporting Assessment, which evaluates the ability of citizen reporters to provide accurate and timely observations from Utah roadways and to fill gaps in existing observation networks; (2) UDOT Operations Benefits, in which the benefits to internal operations as a result of the program will be described; and (3) Traveling Public Response, which assessed feedback from the public regarding the enhanced current and forecast information available to them.

Citizen Reporting Assessment

Hypotheses 1 and 2 from the Evaluation Plan state: "Citizen reports will help to fill observation gaps, spatially and temporally" and "Citizen reporters will provide accurate information to UDOT." This subsection describes what was learned from the tests of Hypotheses 1 and 2.

Reporter Accuracy

Reporter information was very accurate, with less than 1% of the total incoming 651 reports over the 2012/13 winter season being flagged as inaccurate. The reasons for those inaccuracies were determined by the TI Met on duty using other forms of nearby observation (RWIS, cameras, other reports). The ability for TI Mets to verify reports serves as a quality control on the system. Even the few errors that were found during the first season were minor. No flagrantly erroneous reports were submitted, and no reporters had to be warned or removed from the program during the initial season. It should be noted that this was expected due primarily to the fact that all the reporters were UDOT employees who had a good understanding of the need for accurate road weather condition reports.

Ob-Submit Delay

The citizen reporting app allows users to enter the correct time of the report observation. When their submission occurs later than when they have observed the weather and road conditions, the delay between the observation and submission times is defined as the *ob-submit delay*. This measure was used as an indicator of the timeliness and freshness of the information. Analyses of *ob-submit delays* over the season found that the vast majority of reports were indicated as having been submitted at the time of the observation (*ob-submit delay* = 0 minutes), as shown in Table 5-3. Follow-up with CRs found that often an observation time was not changed if the report was delivered within 15 minutes of the observation and weather conditions were not changing. Therefore, there were significantly fewer observation times specified when the submission was made within the first 15 minutes (not shown).

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Table 5-3. Ob-submit delay frequency for all reports over the entire season.

Ob-Submit Delay Category	Frequency of Occurrence	
0 min	462	71%
1– 59 min	89	14%
60 min – 119 min	54	8%
120+ min	44	7%

Source: Utah DOT

The sum of the *ob-submit delay* occurrence values in Table 5-3 yields 651, which varies from the total of 607 reports shown in Table 5-1. The difference is accounted for by the 44 reports submitted at or more than 2 hours after observation. These reports are considered invalid because they exceed the designated 2-hour "fresh data" window, are not included in the analysis, and were not included in road condition updates for the public. CRs should never operate their app while driving, but they should be encouraged to safely report as soon as they are able, or have a passenger report for them, especially within 15 minutes of the observation where feasible and safe. The remainder of the *ob-submit delay* distribution, however, suggests that reports were usually delivered in a timely manner once observed.

Ob-submit delay on rural routes was compared to *ob-submit* delay on urban routes to see if it took reporters on rural routes longer to reach a safe place to submit a report. However, the sizes of the two groups (urban and rural reports) were substantially different and there was significant spread in the rural *ob-submit delay* data, which made it difficult to draw a relationship between *ob-submit delay* and the urban or rural designation of a route. Nevertheless, the data preliminarily suggest that *ob-submit delay* is more a function of the reporter – whether he or she decides to pull over to report immediately or delays until a destination is reached. This analysis should be completed again after the 2013/14 season once the sample size of rural reports has increased and more accurate timing for both observation and submittal are obtained.

Storm day *ob-submit delay* was compared to non-storm day *ob-submit delay* to see if there was any difference in submission timing when conditions were poor or rapidly changing. As noted in Table 5-2 that there were 3 times as many reports submitted on storm days vs. non-storm days, though there were slightly fewer storm days than non-storm. There was a higher fraction of 0-minute *ob-submit delays* on storm days (76%) vs. non-storm days (59%), which may suggest that CRs felt a greater urgency to report when condition updates were most needed. This analysis should be done in future seasons to ensure CRs maintain timely reporting practices.

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Update Gap Analysis

Update gap is a measure of the time between valid citizen reports, when the information is not considered "fresh." It is used to gauge the ability of reporters to supply road condition information at regular intervals throughout the day. For the purposes of this evaluation, the analysis was restricted to an 18 hour period from 5:00 am to 11:00 pm (few reports were received outside that period), and gaps were assessed between reports without consideration of any other road weather information derived from other sources during these periods of time in order to characterize the patterns of citizen reporting independently. In reality the TI Mets receive regular plow driver reports and other relevant data from equipment such as RWIS, cameras and radar (as illustrated in Figure 5-1).

For this project, a citizen report is considered valid for 2 hours after the road condition was *observed* (not submitted), or until the next observation, if less than 2 hours from the previous. Should the ob-submit delay be greater than 0 min, the report will be valid for 2 hours minus ob-submit. The 2-hour increment was established by UDOT because: (1) it adds information to the gaps between the twice-daily TATS reports; and (2) at current staffing and recruiting levels, it is an ambitious goal. Because changing conditions during storms will often render the 2-hour report incorrect in less than 2 hours, CRs should be encouraged to maintain a high level of reporting during these events; and, indeed, the storm day data already suggest that they do.

A detailed methodology was developed to quantify update gaps for each day and is illustrated using 3 example days in Figure 5-5. Note that because 98% of reports were submitted between the hours of 5 am and 11 pm, the analysis will be constrained to that 18-hour period.

In Figure 5-5, red vertical lines represent road condition observation times; orange vertical lines represent submission times, in the event the submission comes in after the observation was made; green, red and blue horizontal bars represent valid reports, invalid reports, and gaps between valid reports, respectively. Letters A-F denote six observation and submission scenarios, and the calculation of update gap in each scenario is explained below.

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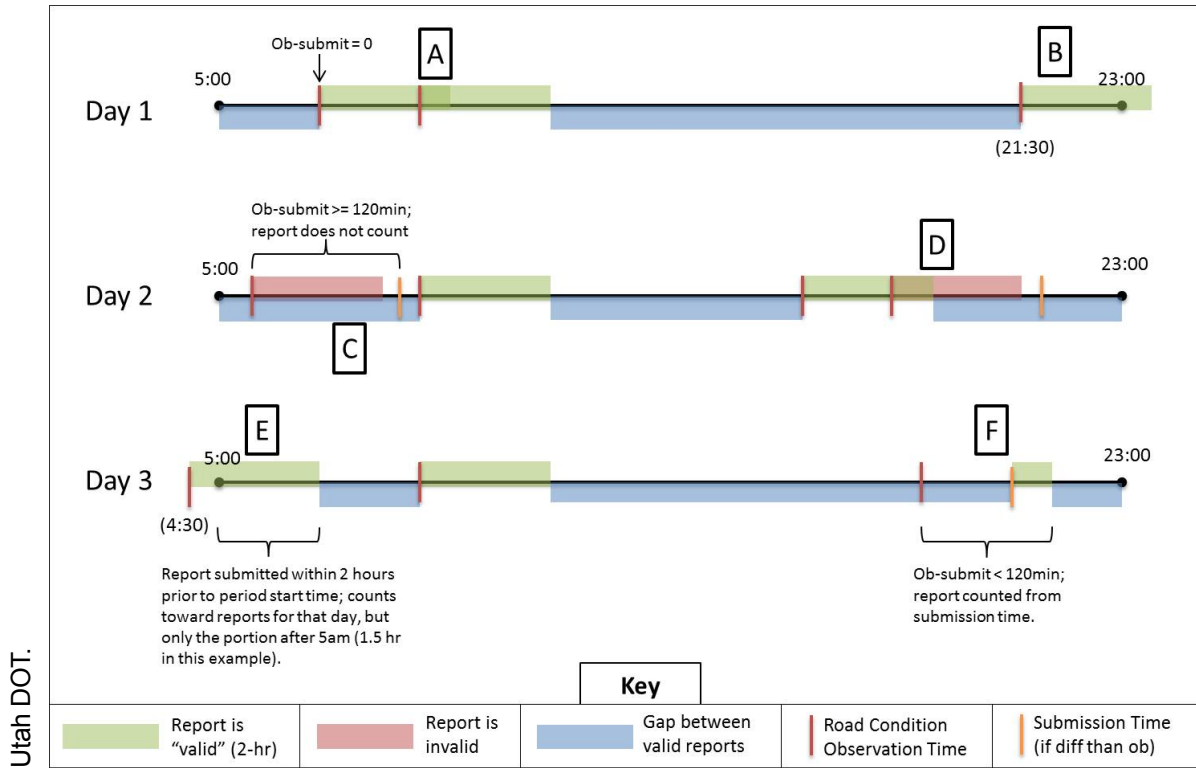
Figure 5-5. Illustrated method of counting update gaps (not to scale).

On Example Day 1, the first gap starts at 5:00 and continues to the first report of the day. That report has a zero ob-submit delay and is therefore valid for 2 hours, but another report comes in during that time (A). The second report also has a zero ob-submit delay and is valid for 2 hours, so the next gap starts 2 hours after the second report and continues until the third report at B. The final report of the day occurs less than 2 hours before 23:00, so no gap is counted for the rest of the day.

On Example Day 2, the first report is submitted more than 2 hours after the observation was made (C), so the report is not counted. Thus there is a gap in reporting from 5:00 until the first valid report is received. At D, an invalid report overlaps with a valid report, so the reporting gap begins at the end of the valid report, ignoring the invalid one.

On Example Day 3, a report is submitted less than 2 hours before 5:00 (E). In this instance, the report is valid through the start of the morning, and the first gap starts afterward. The example at F illustrates how a report's valid time is shortened by an ob-submit delay that is greater than 0 min and less than 120 min. Because a user of the information would not see the report until it is actually entered, the gap continues to the submission time, but is still only valid for 2 hours after the observation was made.

Using this methodology, the average size (in hours) of the gaps between valid reports was calculated on each day with at least 1 report, Dec 2012 – Mar 2013, for all segments receiving reports. The calculation was also constrained to primary, secondary and tertiary segments, as well as to storm days and non-storm days. The results are shown in Table 5-4. Note that because the average gaps are greater than 7 hours, they are all large relative to what an objective of complete coverage would yield, which would be a daily average gap of 0 hours. As discussed below, an objective of 0 hours will

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be extremely difficult to reach precisely, but UDOT can focus on other ways to optimize the distribution of incoming road condition reports.

Table 5-4. Average update gap on days receiving at least one report.

(hours)	All Segments	Primary	Secondary	Tertiary
All Days	7.5	7.5	7.7	7.4
Storm Days	7.3			
Non-Storm Days	7.9			

Source: Utah DOT

The average calculation yielded fairly similar values (within about a half-hour), whether constrained to particular segments (P, S or T) or particular days (storm or non-storm). These similarities reflect the predominance (nearly 90%) of days in which only 1 report was submitted per segment, each of the 1-report days having an average gap of 8 hours. That is, if only 1 report is entered and that report is valid for 2 hours, the sum of the two gaps on either side of the report is 16 hours, with an average 8 hours. Thus, with increased reporting average update gaps decrease per day, but only slightly when averaged over many segments and/or days. Note, for example, the storm day statistics in Table 5-4: since reporters are 3 times more likely to report on storm days (from the Descriptive Statistics section), we'd expect that there would be decreased gaps between valid reports, and in fact the gap is an average 0.6 hours less on storm days vs. non-storm days.

Of the primary, secondary and tertiary designations, tertiary segments, with an average of more than 3 active reporters per segment, have the shortest average update at 7.4 hours, followed by primary and then secondary. Despite there being more CRs assigned to and active on secondary vs. primary (from Table 5-1), CRs on primary segments reported more often per day, resulting in a smaller average update gap. Thus, while UDOT strives to concentrate CRs on primary segments, multiple reporters assigned to each of those segments will yield even better coverage. Furthermore, CRs should also be reminded to report multiple times per day when possible.

Not only is an increased number of reports per day important, but the distribution across the day is also important. To verify this logic, average update gap was calculated on the most highly reported day for each of the 5 segments with the greatest number of active reporters. The results of this analysis are displayed in Table 5-5. Letters A-E are included in the first column as road segment identifiers.

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Table 5-5. For segments with the most active reporters and on a single day with the most reports, number of reports and resulting average update gap for each day.

ID	Segment	Date with Most Reports	# Reports	Average Report Update Gap (hr)	Largest Gap Each Day (hr)
A	I-215 Salt Lake Westside Belt Route	12/6/2012	5	4.5	9.9
B	I-15 Provo to Spanish Fork	12/18/2012	4	3.7	5.1
C	I-15 Orem to Provo	12/18/2012	5	2.3	5.1
D	I-80 Parleys Canyon	12/19/2012	2	7.9	11.5
E	I-80 Through Salt Lake	1/11/2013	2	5.2	11.8

Source: Utah DOT

Segment A received more reports on its most active day compared with Segment B (5 versus 4), but the update gap was greater for A (4.5 versus 3.7), because out of the 5 reports submitted on 12/6/12, 2 were submitted during the 10:00 hour, and 2 during the 11:00 hour. As a result of the overlap or clustering of several reports early in the day, there was a large gap without any updates later in the day (9.9 hours). The 4 reports entered on 12/18/12 for Segment B were more evenly distributed throughout the day (midmorning through afternoon and evening), thus reducing the average and largest update gap. Therefore, assuring a distribution of reports throughout a day is important in maintaining refreshed information and keeping data gaps as small as possible throughout the day.

When Segment A is compared to Segment C, the importance of distribution is emphasized further. The 5 reports received on 12/18/12 for Segment C were entered at 10:06, 11:40, 13:05, 15:47 and 18:39, and each was valid for 2 hours, yielding only a few hours without valid data over the whole day. There was an initial gap of 5.1 hours prior to the first report, but the well-distributed reports throughout the remainder of the day reduced the gaps in information thereafter, resulting in a low average gap of 2.3 hours. Segment C is a prime example of how well-distributed, valid reports can maintain up-to-date information along a roadway.

Similar to the relationship between Segments A and C, Segments D and E had the same number of reports each day (2 each), but the 2 reports entered for D were so close to each other that the average gap for the day was much greater for D than for E (7.9 hours versus 5.2 hours). However, the largest single gap for each segment was almost the same (11.5 hours and 11.8 hours respectively), despite nearly 3 hours difference in the average. These largest gaps are again caused by the time of day clustering of when the reports were entered. Each day's reports were grouped either in the morning or in the evening, leaving a gap of over 11 hours on the other end of each of these days. Thus, it is important that reports are well distributed throughout the day with minimal or no overlap, thereby keeping both the average gap and the single largest gap as small as possible.

Still, even with the most uniformly distributed citizen reporting data, in which no reports overlap over the entire day, there will be a lower limit to the average update gap size. Numerically, it is expressed as:

$$UGLimit(day) = \frac{DayHours - \#Reports \times 2}{\#Reports + 1}$$

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where *UGLimit(day)* is the lower limit for average gap size for a given day, *DayHours* is the total hours in the day (18 hr, for the analyses herein), and *#Reports* is the number of reports received over the day. Graphically, a uniform distribution is shown in Figure 5-6. Table 5-6 displays the results for *#Reports* = 1 through 9. For a day with 1 valid report, the smallest possible average update gap possible is 8 hours; for 2 reports in a day, the smallest possible update gap is 4.7 hours; and so on.
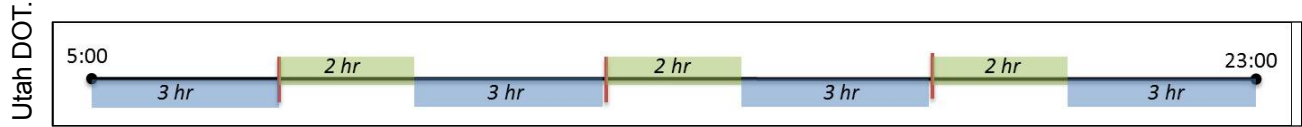
Figure 5-6. A hypothetical model of three uniformly distributed citizen reports throughout a day and the resulting 3-hour gaps between.

Table 5-6. For a single 18-hour day with ideal report distribution, the smallest average update gap possible per total daily reports.

# Reports	Smallest Average Update Gap Possible
1	8 hr
2	4.7 hr
3	3 hr
4	2 hr
5	1.3 hr
6	50 min
7	30 min
8	15 min
9	0 min

Source: Utah DOT

Notice that only with 6 absolutely optimally distributed reports constrained to an 18-hour day would the average update gap drop below 1 hour. Therefore, an objective of a 0-hour average update gap will be a substantial challenge (requiring at least 9 reports a day), as will attaining an optimal distribution of reports. Fortunately, when reports are clustered, road condition information is kept updated more often over a smaller portion of a day. This will be most important during storms and changing weather conditions. Analysis of the first season already shows that CRs report more often during storms, which increases the likelihood of clustered reporting and shorter update gap times when reports are needed most.

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Recruitment and Training Recommendations

The analyses above highlight important recommendations for UDOT's recruitment and training in future seasons (greatly expanding the number of reporters). For recruitment, UDOT should:

1. continue to focus on recruiting for routes with the least adequate data (primary), and
2. recruit groups of reporters with diverse driving (and hence reporting) times.

Throughout the season, it will be important to maintain communication with CRs so that they stay engaged and active and so that TOC staff can troubleshoot any issues encountered. UDOT also trained CRs to report on the worst conditions along route, ideally having visited the summit or climatologically most hazardous portion of a route. One of the benefits of assigning CRs to a given route is that they are usually very familiar with the route and how road conditions develop along it in certain weather. Finally, not only should CRs be trained to report often and in a timely manner during storm events, but also to report consistently when the weather is clear. Consistent reporting in all conditions maintains the habit of reporting and keeps the information refreshed.

UDOT Operations Benefits

Because citizen reports and the travel forecast will not only be available to the traveling public, but also to internal UDOT personnel, the analysis in this section tests Hypothesis 3 by assessing the benefits experienced by UDOT Operations as a result of the program. It was hypothesized in the Evaluation Plan that (a) traffic operators will benefit from enhanced situational awareness, (b) meteorologists' ability to produce and verify forecasts will improve, (c) traffic operations managers will make well-informed decisions and will learn from post-storm reviews, and (d) other UDOT groups will be able to use the real-time citizen reports to improve performance. Because outcomes a, b and c involve TOC-specific benefits, they will be described together. Data constraints this season did not allow for a complete assessment of the benefits to UDOT groups outside of Operations; however, future evaluation activities should revisit this analysis.

TOC Benefits

The UDOT TOC has a unique structure in that the contracted meteorological firm and UDOT-employed meteorologist are located alongside of, and work in conjunction with, traffic operators and managers. Thus, information exchange is facilitated through direct interaction. UDOT meteorologists also have a close relationship with UDOT Maintenance crews and managers by issuing twice daily maintenance forecasts and engaging in regular phone interaction with crews in the field. Thus, as the predominant receiver, translator and communicator of weather information for UDOT (refer back to Figure 5-1), the meteorologists directly benefit from incoming citizen reports, and can provide enhanced service to the remainder of UDOT Operations.

The meteorological forecast process is highly influenced by the availability of field data, especially in complex terrain. RWIS stations, cameras and radar are regularly used by meteorologists to assess current conditions, but Utah's many rural and mountainous routes suffer from large gaps in observation, as discussed in the previous subsection. The addition of citizen reports introduces a unique, low-cost method for adding observation throughout the state. Despite the fact that a highly concentrated CR dataset was not available during the initial season of the program, important benefits have already been recognized.

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Interviews with TOC Meteorologists revealed that the addition of CRs aids the forecast process – production and verification – and, overall, keeps the weather office more aware of the situation and able to relay weather alerts as needed. One example from this season:

> *…The report was for US-89 in Logan. I suspected there was road snow in Logan for a few reasons, but I could not confirm this due to the lack of observation in the valley. I received a report of road snow in Logan from a Citizen Reporter. This report helped verify what I thought was happening in the Cache Valley.*

And another:

> *A report was received for wet roads and rain in the Cove Fort area after the wet weather was forecast to be over. Cove Fort is typically in a radar hole in a stratiform* [from low-lying stratus clouds] *or upslope precipitation regime (which was likely the situation in this case). The* [citizen] *report alerted the Traveler Information Meteorologist that precipitation was still falling in that area and the TATS segment was updated with more accurate information.* [Because CRs were not available publicly this season, the information was updated through the public-facing TATS system.]

Regarding the latter instance, the meteorologists pointed out that this increase in situational awareness is helping to improve overall pattern recognition. That is, with the improved field reporting, they are better able to link certain regional-scale weather patterns to localized impacts in regions previously lacking adequate observation. In fact, the meteorologists have noticed for years that their forecasts are most accurate in maintenance areas in which the plow crews give the most feedback on road weather reports at ground level. The increased success only continues to add value to an already valuable program.

Current practice is for the meteorologists to call a maintenance crew and to alert traffic operations when unexpected conditions are seen. Meteorologists reported that CRs only enhance their ability to do so, mentioning that multiple times over the season, they were able to use incoming CR information to pass along valuable updates to operational staff. In the event that reports are clustered during storm events (as discussed in Citizen Reporting Assessment above), the validity of the reports is improved even further. With operational benefits already realized during the initial season, it is assumed that benefits will only increase as the program expands.

Traveling Public Response

Hypothesis 4 addresses the response from the traveling public, particularly to the enhanced travel forecast portion of the program. Recall that the enhanced forecast increased the frequency and extent of the previous season's travel forecast to 3-hour increments extending 24 hours into the future, and included 6 additional routes (details in Appendix A). Response was measured using a public survey and a public focus group that were performed during the season. Overall, the results suggest a positive public reaction.

Public Survey

The evaluation benefited from a traveler survey which was already occurring during this season. The survey was a joint project between the National Weather Service (NWS) office in Salt Lake City, the University of Utah, UDOT and the University Corporation for Atmospheric Research in Boulder, Colorado. There were two sample periods, which took place in the days immediately following two winter storms – Jan 10, 2013 and Jan 24, 2013 – which had significant impacts on transportation in

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the Salt Lake City metro area. After each, 400 phone surveys were conducted with citizens who regularly travel through the area. The survey was a larger effort to assess the public's use of forecast information from a variety of sources (media, NWS, UDOT) for travel planning purposes and their satisfaction with each source. However, the analysis here focuses specifically on the UDOT-related responses.

Figure 5-7 shows responses to the question, "Did you use [this source] for information about the storm?" Overall, survey responses showed that local media (TV and radio) were the most highly used. 35-50% of respondents received storm information from the local media while 5-10% used UDOT Traffic forecasts and 10% used NWS forecasts. This was not an unexpected result. It has been previously shown that the majority of drivers receive forecasts through local media outlets. In response to this, there has been a significant effort over the past few years between the UDOT weather group and the Salt Lake City NWS Forecast Office to collaborate on better traveler-focused forecasts, creating a shared message, and making it widely available to the local media. In this way, local media and the receiving public are able to benefit through enhanced travel forecasts indirectly. Additionally, educational public outreach has been a mission of the UDOT Road Weather Group in recent years. Direct benefits to the public will also be realized as the popularity and use of UDOT's information outlets increase.
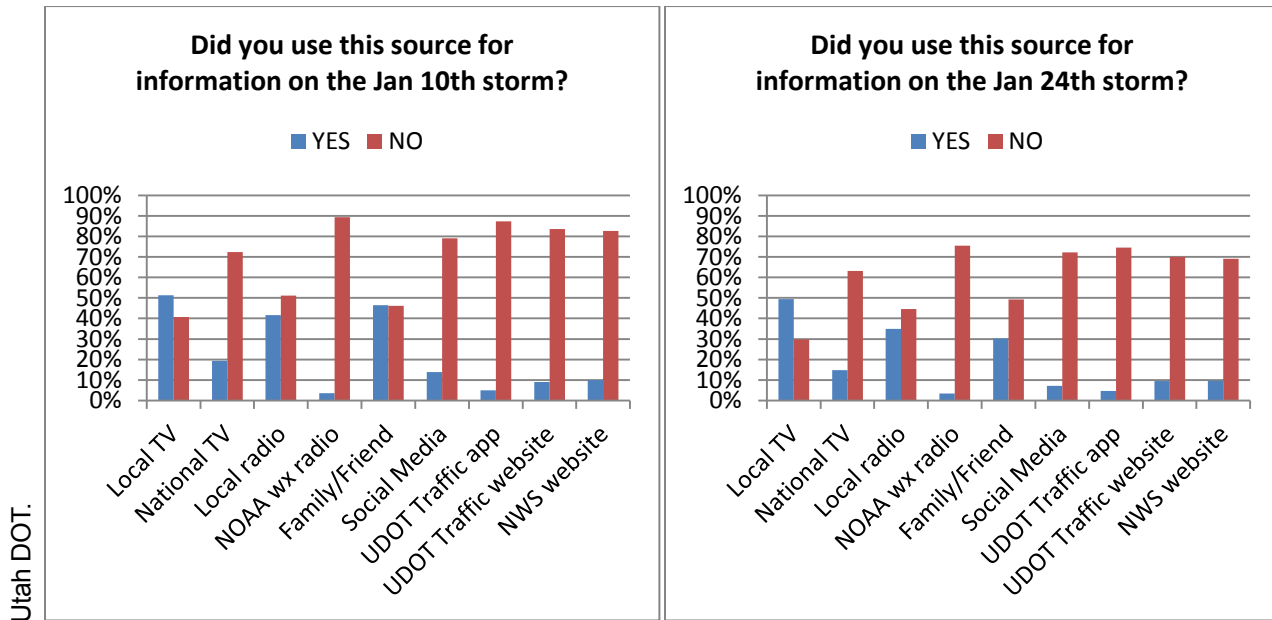
Figure 5-7. Responses from 400 survey participants who frequently travel in the Salt Lake City metro area. The "Not Sure" responses are not shown.

Of those who used the UDOT Traffic app or UDOT Traffic website, each was asked whether they were satisfied, unsatisfied or a mix of satisfied and unsatisfied with the forecast information. Figure 5-8 displays the results from each storm, Jan 10th and Jan 24th, and the numbers of respondents are listed in the caption. 95% and 83% of respondents were satisfied with information received from the app for each storm, respectively. 81% and 76% were satisfied with information from the website, including 11% who reported a mixture of satisfied and unsatisfied.

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There are subtle differences between each storm and each information outlet. First, the UDOT Traffic app usage is about half the size of the website usage. This is not surprising, as the website is more readily available to a larger segment of the population. Second, the satisfied responses are slightly larger for the UDOT Traffic app than for the website. Even with such a small sample size, this may reflect that UDOT Traffic app users in general have been very satisfied with the information and the way the information is displayed. The UDOT Traffic app ratings on both iOS and Android operating systems are each about 4.5 out of 5.

Third, the slight decrease in satisfaction between the 1/10 and 1/24 events may reflect the varying natures of each storm. The storm on 1/10 was a cold front that brought snow-covered roads to the Salt Lake Valley just prior to the evening commute. It is a scenario that Wasatch Front travelers are accustomed to, as late afternoon cold fronts are a climatologically frequent occurrence in northern Utah. The event and the impacts were straightforward, and many travelers chose to leave work early. (Anecdotal evidence suggested that the evening traffic peak may have occurred prior to 5:00 pm; traffic data were unavailable on this day.) The storm on 1/24 was a rare freezing rain event that struck the Wasatch Front during the early morning commute, leading to ice covered roads across the valley and causing major traffic impacts. Freezing rain is extremely rare in Utah, averaging one event every 7 or 8 years. The forecast impacts may have either been understated or the public read them as such, and so there were fewer "satisfied" responses in Figure 5-8. Nevertheless, the data suggest that, by and large, the public is satisfied with the forecast information provided on UDOT channels.
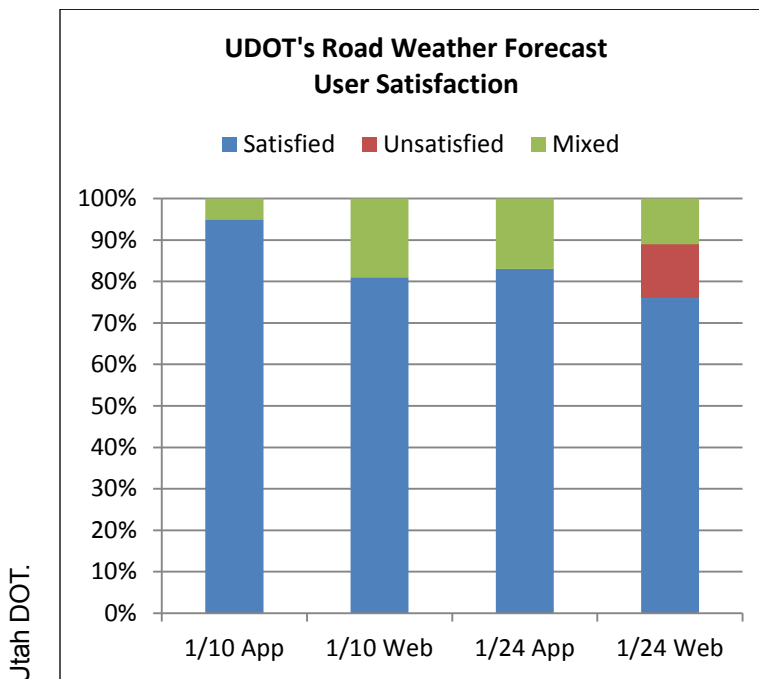
Figure 5-8. Satisfaction of survey participants who used the UDOT Traffic app or website during each storm. There were 20, 36, 19 and 38 respondents for each column, left to right.

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Public Focus Group

A focus group was held on April 16, 2013 and was a joint effort between the Wx-TINFO Project Team and UDOT Communications Division. The objectives were to:

- Identify public attitudes and perceptions relating to the effectiveness of UDOT's communication tools.

- Understand public opinions toward the UDOT Citizen Assisted Reporting Program.

- Gauge the impact of UDOT communication about travel conditions on citizens' travel choices and behaviors.

- Assess drivers' impressions of the quality and quantity of travel condition information UDOT communicates.

The sessions consisted of two groups totaling 19 participants and consisting of public motorists who frequently use UDOT Traffic sources for traveler information.

The following were findings relevant to the Wx-TINFO project:

- UDOT Traffic app is most often accessed during adverse weather.

- Drivers appreciate real-time, accurate weather information.

- Where available and when the image is clear, cameras are an effective tool to view travel conditions.

- The Citizen Assisted Reporter Program is seen as a good way to increase the availability and accuracy of weather and traffic information.

The groups offered some concerns and recommendations, as well. Table 5-7 lists the concern or recommendation and a comment on UDOT's action in response.

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Table 5-7. Public responses from the focus group.

Public Concern or Recommendation	UDOT Action
UDOT should ensure that volunteers are properly trained, are followed-up with and report consistently, and that the program is quality controlled.	Each CR is routinely trained, TI Mets constantly survey the incoming reports for accuracy, and UDOT's TI Manager maintains communication with the CRs through the season.
Tell the public the source of the observations; they will trust them more.	Work is underway at UDOT to accomplish this.
Quicker updates are preferable.	As the Citizen Reporter Program grows, condition updates will become more frequent. Nevertheless, TI Mets will continue to maintain 2-hourly updates of road conditions as needed.
Personalized alerts were requested.	This has been logged for future consideration.
A radar animation (which is not currently available on UDOT's TI outlets) was requested to help travelers understand the spatial and temporal nature of precipitation.	This has been logged for future consideration. Note that, when used in conjunction with roadway reports, radar will be even more valuable because it will give the user information on precipitation location, type and road impacts.

Source: Utah DOT

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Chapter 6 Conclusions and Lessons Learned

The goal of this project, as discussed in Chapter 3, was "to provide both TOC operators and travelers with more accurate and timely road weather and travel impact condition information and forecasts." UDOT is developing their citizen reporting program in order to supplement their primary existing sources of road weather information from RWIS Environmental Sensor Stations, radar, cameras, and plow driver reports. Three of the four objectives under this goal were related to expanding the frequency and time horizon of the road weather forecasts, extending the forecasts to 6 additional state routes, and implementing the software changes needed to manage and disseminate these data to travelers. Each of these goals was successfully met by mid-January 2013. The evaluation discussed in Chapters 4 and 5 was focused on the fourth objective of developing and implementing a preliminary citizen reporting system and evaluating public response to the road weather forecasts. As indicated, this evaluation was conducted primarily to help guide future program development as it evolves in the coming years, based on the experiences from this limited, preliminary implementation. The conclusions and lessons identified in this chapter are offered as constructive suggestions to strengthen the citizen reporting program going forward, in addition to assessing the performance that was achievable during this initial test season.

This project has demonstrated UDOT's ability to add citizen reporters as a viable and useful source of road weather information to supplement their primary resources. In order to assess the performance and effectiveness of citizen reporting in this preliminary implementation and to simplify the analysis, the evaluation has focused only on coverage achieved during this period by the citizen reporters. As UDOT rolls out the program to a larger group of trained reporters in subsequent years, the frequency and the coverage provided will necessarily increase allowing for new applications for traveler information and traffic management to emerge. It is important to note that UDOT does not ever expect the CR program to achieve complete coverage or replace any existing sources of information. However, the value of the citizen reports to UDOT has been well established with this evaluation.

With this in mind, the initial citizen reporting implementation has provided several important lessons learned that will seek to optimize their reporting in the following ways:

- To the extent possible recruit CRs in order to populate the key primary segments and times of day when observations will be needed, and overall seek an even distribution of anticipated reporting by location and time of day to minimize gaps in the availability of fresh road weather data, and avoid long time gaps or road segments with no observations (CR reports).

- Reports submitted over this initial period were uniformly accurate. When recruiting less experienced citizens in the future, it will be important to emphasize the training, monitoring and follow-up to assure such high levels of accuracy in reporting.

- Prioritize reporting to the primary and secondary route segments where observational data are most needed.

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- Encourage all trained CRs to actively report, and monitor their activity to provide support and encouragement as needed. When activity monitoring identifies segments, times of day, or days of the week, that are notably underrepresented with reports (i.e., experience persistent and large reporting gaps), consider reassigning CRs or replacing CRs in overrepresented segments with new recruits who can report in the underrepresented situations. As necessary, recruit new CRs for the situations experiencing the greatest gaps in road weather information.

- Consider including push notification capabilities to the CR reporting app so that CRs can set alarms to remind them to report at their usual reporting times during the day.

- The majority of reports were timely in their submission (short *ob-submit* delays). However, given evidence in this initial implementation that some CRs had difficulty specifying (or estimating) the actual time of observation, particularly when there was a time lag between observation and report submittal, consider a simple way that the CR could indicate on the CR App when they made their observation. This would have to be implemented in a way that wouldn't cause driver distraction or pose a safety risk. When the CR submitted their report, the transmission would include time stamps for both observation time and submittal time, thereby allowing for an accurate calculation of the ob-submit delay.

- Quickly identify any reporting problems, including technical issues with the CR reporting App, and work with the CRs to resolve them.

- Emphasize the importance of providing reports prior to, during and after forecasted storm events for as long as the event continues to impact road surfaces and traveler mobility and safety.

- In both training and follow-up with the CRs, encourage submission of their road weather reports within 15 minutes of the observation time, without jeopardizing safety considerations, and emphasize the importance of recording observation times accurately in order for UDOT to properly gauge the freshness of the report.

- Recognize that in future implementations the CRs will primarily be regular citizens, and not all experienced transportation personnel on UDOT staff as they were in this initial implementation. This means UDOT will likely need to spend additional time on training and monitoring and may need to provide more support than was required during this implementation to assure the reporting functions smoothly and meets expectations.

During this initial implementation of the CR program, the TI Mets were responsible for receiving, screening and processing all the reports submitted by the CRs. The expectation was that the availability of current, reliable observation data would supplement other traditional road weather data and information and thereby enhance the content and quality of UDOT's road weather forecasts. Having CR reports submitted from the more remote, rural primary segments would be especially beneficial and should help reduce the time spent by the TI Mets in their efforts to arrive at useful forecasts. Although the documented instances in which CR reports caused the TI Mets to alter a forecast or distribute information they otherwise wouldn't have been able to provide in the absence of the CR program were few, some important lessons were derived from this experience.

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- Even though the TI Mets didn't adjust many forecasts based on available CR reports, the reports they did receive were considered very beneficial based on the increased confidence and ground-verified data they provided the forecasters.

- It is important to understand that CR observations are combined with a variety of other data sources (plow driver reports, camera images, radar, etc.), and, except for the most remote route segments that lack any other road weather information sources, the CR reports help fill out a partial mosaic of road weather information available to the TI Mets.

- Going forward from this initial CR implementation, it will be helpful for the TI Mets to thoroughly document how they used the CR observations to strengthen the case for the value of this program and to show how it usefully supplements all the other sources of information to paint a more complete picture of current and future conditions on UDOT's road system.

- While the limitations of the capacity of CRs to fill all the observational gaps in available road weather information has been noted, there are still important benefits to having overlapping observations from CRs. Multiple sources of information on critical locations available during critical times help confirm and strengthen the TI Mets' ability to make road weather forecasts with confidence. Report clustering also draws particular attention to potential problem segments due to poor or dangerous road weather conditions. Given the likelihood that there will continue to be gaps in information in some segments at some times of day and days of the week, even with a large number of CRs actively reporting, the preference will likely be to seek to fill those gaps as best as possible; nevertheless, the inevitable overlapping reports will still provide UDOT value.

In conclusion, the addition of citizen reports will help fill gaps in available road weather data, provide for "fresher" data than have been available in the past, support UDOT's plans to enhance their road weather forecasts, and help meet state and national transportation goals for safety and mobility during weather events. In the longer term this program is expected to raise awareness throughout the state of Utah regarding the challenges to safe driving during adverse weather and the benefits offered by new tools and better information to aid travelers in avoiding or handling potentially dangerous driving conditions. Finally, the lessons from this initial implementation will help UDOT further develop this program going forward and serve as a beneficial model for other state DOTs that seek to implement similar improvements.

Moving Forward

It is important to note that Utah DOT is currently making adjustments to their citizen reporting program utilizing many of the lessons learned documented herein from the initial implementation. They are planning to implement these adjustments and expand the program for the coming winter season.

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Chapter 7 Recommendations

Implementation of WRTM strategies continues to gain steam around the country and positive examples such as UDOT's traveler information strategy implementation project provide the evidence necessary to continue pushing toward greater deployment of WRTM. This recommendations section is intended to assist FHWA in its efforts to champion the program and expand their partnership with State DOTs. Recommendations provided here recognize the particular implementation phase of the WRTM program and are aimed at identifying and deploying the next set of WRTM strategies at agencies willing to move beyond a demonstration or a pilot phase.

Recommendation #1 – Identify and support the next set of WRTM Implementers for Wx-TINFO

Improving traveler information practices for WRTM continues to be an expressed need in the road weather stakeholder community. Leading examples such as UDOT's project show how Wx-TINFO can help agencies increase their awareness of the conditions, incorporate new road weather data sources, and also provide actionable information for both current and forecast conditions. The UDOT experience reveals the positive public reaction to such implementations as well. The current Wx-TINFO concept provides a good starting point for agencies considering improvements in their traveler information programs during adverse weather without being overly prescriptive. The success of this project in creating operations-ready projects needs to be replicated at other locations around the country.

Recommendation #2 – Support the inclusion of mobile data sources in WRTM ConOps

Mobile data collection, processing and use in road weather management promises to launch the next generation of WRTM strategies. By overcoming the limitations of a fixed detection infrastructure, mobile data is poised to provide a vastly enhanced dataset for motorist advisories, alerts and warnings. Additionally, mobile data can also support more effective road maintenance activities. The UDOT Wx-TINFO project clearly illustrates the value of mobile data through an effective citizens reporting program. However, there is a greater potential to be realized in terms of sensor-based mobile data mounted on various DOT vehicles. Other vehicles such as state/highway patrol cars, goods transport trucks, or even individually owned cars are possible candidates. In the next implementations it is necessary to consider the creation of such data and their role in WRTM.

Recommendations #3 – Continue to build on the partnerships with UDOT

UDOT's continued leadership in WRTM and their innovative approaches provide FHWA with a state-of-the-art example of traveler information program during weather conditions. FHWA should continue to identify and provide opportunities for UDOT to share their experiences and provide peer support to other agencies considering similar approaches, pending UDOT's willingness and availability to do so. Other projects and partnerships with UDOT in road weather need to be explored as appropriate to support UDOT's continued advancement in this area.

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Recommendation #4 – Continue research and monitoring of Citizen Reporting Practices for WRTM

Citizen reporting practices are being considered in several states other than UDOT as an effective way to gather observed condition information from the traveling public. Wyoming and Idaho are neighboring States that have similar programs. Interest in citizen reporting has been expressed by the Enterprise Pooled Fund and the I-80 Corridor Coalition. As such, the evolution of the citizen reporting program in UDOT is of great interest to the larger road weather community. Additional information on topics such as recruitment, training, required amounts of coverage, latency, data quality and reporting of citizen data are expected to become available over the next winter in Utah. Similar citizen reporting programs are being promoted by NOAA[2]. A synthesis of existing best practices is timely and relevant to stakeholder needs and could provide a set of best practices for other states who may be considering citizen reporting programs.

Recommendation #5 – Build in a longer project development cycle for WRTM projects

In developing the recommendations, two unique lessons learned from this project are of particular importance – the short time frame for system development, and the required integration of the project into day to day operations. The short time frame presented particular challenges to following a structured systems engineering process, and the inclusion in day to day operations created a challenge in terms of developing the adequate procedures necessary for seamless integration in parallel to systems development. Both these facets can be ameliorated with a longer project development cycle. A longer project development cycle allows for a more robust requirements development which pays off once the system is designed and transitions into operations.

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[2] http://www.nssl.noaa.gov/projects/ping/display/

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APPENDIX A – Utah Department of Transportation (UDOT) Traveler Information System, Concept of Operations

Introduction

The purpose of this document is to explain the overall concept of the Utah Department of Transportation's (UDOT) Weather Responsive Traffic Management (WRTM) – Traveler Information Strategy Implementation – project. The document will provide a summary of the current system, how the proposed changes will be carried out and how those changes will benefit UDOT's traveler information program.

Project Overview

Current and forecast weather conditions are a critical part of traveler information in Utah. Utah has many high mountain passes and rural routes that frequently experience hazardous winter weather, and accurate road condition information for these routes is vital for traveler safety and route planning. Additionally, almost all of Utah's non-recurring urban congestion occurs as a result of weather. Following large winter storms, UDOT holds After Action Report (AAR) meetings to quantify the delay caused by the event, UDOT's messaging, and other storm factors. For several of these storms, UDOT has data that can support how the messaging and creation of situational awareness has an impact on traveler decisions. When provided with accurate weather information, travelers can make changes in their travel behavior, plans, or preparedness thus possibly reducing the potential for congestion and weather-related crashes.

Currently, the Utah Department of Transportation posts current and forecast conditions on the UDOT Traffic website, 511 Traveler Information phone line and the UDOT Traffic smartphone application. At this time, the reports are of fairly low spatial and temporal resolution. The increased ability for travelers using the mobile app to access real time data has spurred an effort to enhance the weather data available to travelers pre-trip and en route. Since its launch, the UDOT Traffic app has been downloaded over 92,000 times. It has been an excellent resource for distributing traveler information to the public. Because of its heavy usage, data on the app is more highly visible than ever, which puts more demand on real time, up to date, and accurate data.

The Citizen Reporting component of this project enlists selected and trained personnel to report on current road conditions along specific roadway segments across Utah. The personnel could be UDOT employees, law enforcement, truck drivers, plow drivers, experienced commuters, or other volunteers. Citizen Reporters would be trained yearly on what to report on and how to provide accurate road weather reports. While initially starting with a small sample in this project, the end-goal is to enlist 8-10 citizen reporters per route segment with a total of 800-1000 reporters. The long term goal of adding Citizen Reporters to UDOT's weather operations road reporting is to supplement current condition reporting on segments where drivers are already traveling. Many of the segments selected for the pilot testing are areas where there is no infrastructure to install an RWIS or traffic camera; however, the route is a busy winter route. The TI Meteorologist staff carefully selected test segments based on weather patterns and adjacent routes that are currently reported. The citizen reporting component of this project is designed to enhance UDOT's coverage of road weather reporting on under-reported segments throughout the state of Utah. If the first season implementing this concept is successful, the long term goal will be to add additional routes and expand the number

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of citizen reporters. The first season will be utilizing a total of approximately 100 reporters. Those reporters will be selected from each of UDOT's four regions, the TOC, and UDOT's central office.

UDOT has a network of RWIS and traffic cameras that can help to create a road conditions report. UDOT also utilizes reports from its plowing maintenance crews; however, the crews are only required to report conditions twice daily or as conditions change. See diagram below in the "Concept for the Proposed System – Road Weather Sources" section for a visual explanation of how the Citizen Reporting component fits into UDOT's road weather reporting process.

The Traveler Information Meteorologist (TI Met) component of this project will hire two additional meteorologists based at the UDOT Traffic Operations Center (TOC). The focus of the additional meteorologists will be to produce road weather impact forecasts for travelers. To do this, they will utilize citizen field observations, RWIS, radar and satellite data and weather models to produce road-specific forecasts. They will relate this weather information to the public by describing the impact that the weather will have on road conditions and traffic. They will also serve as TOC-based quality control for incoming road condition reports from citizen reporters.

Referenced Documents

- Guidelines for Disseminating Road Weather Advisory & Control Information – Publication Number FHWA-JPO-12-046
- Developments in Weather Responsive Traffic Management Strategies – Publication Number FHWA-JPO-11-086

Current System

Current Weather Reporting

Road condition reporting occurs on all Utah state routes, which are broken into a total of 140 reporting segments, called TATS (traveler advisory telephone system) segments. Currently, 11% of the segments, mostly urban, are reported on using visual verification of conditions by traffic operators on an hourly basis. The remaining 89% of segments, mostly rural, are reported on by UDOT field personnel at least twice daily. There is not currently a Citizen Reporting component of the existing system. Stale and incorrect reports often result from lags in reporting from field personnel.

UDOT's Weather Operations forecast provider currently produces road weather forecasts for significant routes throughout the state. These routes include interstates and major US routes in Utah, and the forecast is divided among the TATS segments along these routes. The forecast is an 18-hour travel impact forecast, which is divided into three 6-hour increments. Expected weather, road condition, and impacts to traffic are forecast. Impact is ranked as none/minimal, moderate/intermittent, or high/travel impaired. Each impact level is associated with recommended actions to be taken by the traveler.

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Utah DOT.
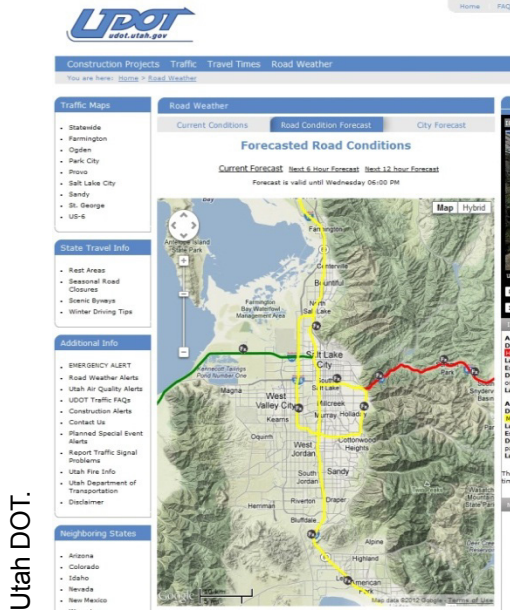
UDOT's "Red/Yellow/Green" Winter Forecast Page

The maps shown below indicate the current road segments that are reported to the public. The map on the right shows a breakdown in existing segments, new segments and current conditions segments. The additional TI Meteorologists and the Citizen Reporting Program will assist in populating the data for these segments on a more frequent basis.

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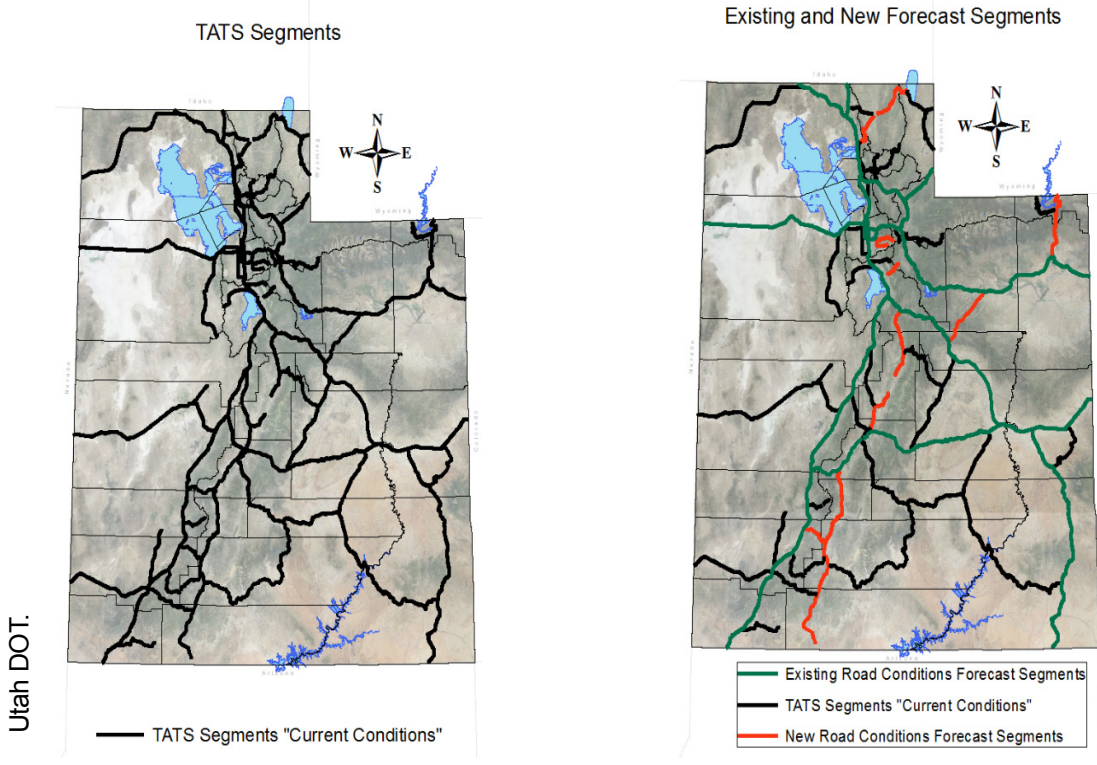
<u>Current Traveler Information Dissemination Methods</u>

UDOT has a number of traveler information resources available to the traveling public. The TOC receives a wealth of information that can be valuable to travelers regarding construction projects, special events, weather events, crashes, and other incidents that can cause delay.

- UDOT Traffic Website and Mobile Website – Launched in 1996, the UDOT Traffic website (formerly the CommuterLink website) hosts an average of 93,000 unique visitors every month. The website has traffic information, weather forecasts and "nowcasts", a Frequently Asked Question section, and other resources. Travelers can sign up for email or text message traffic alerts for routes selected by the user.
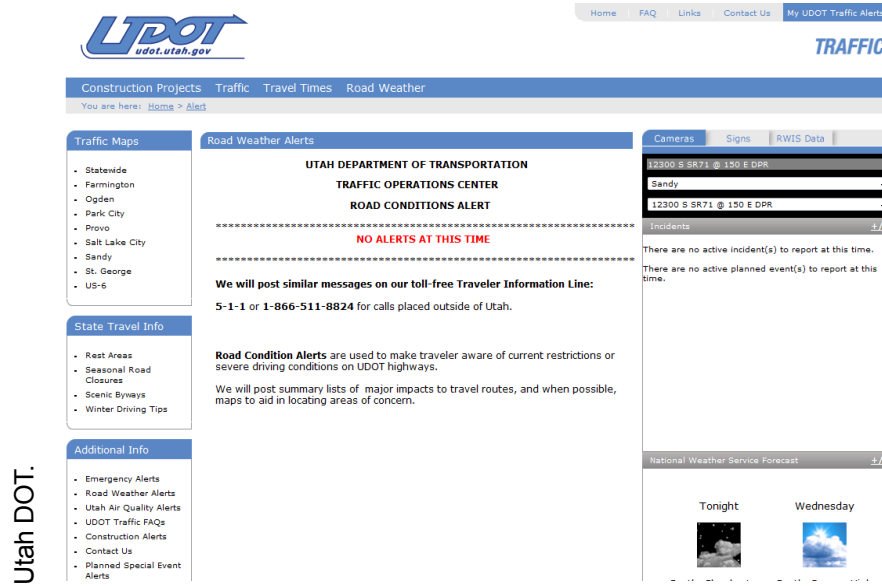
The Road Weather Alert section of the UDOT Traffic website
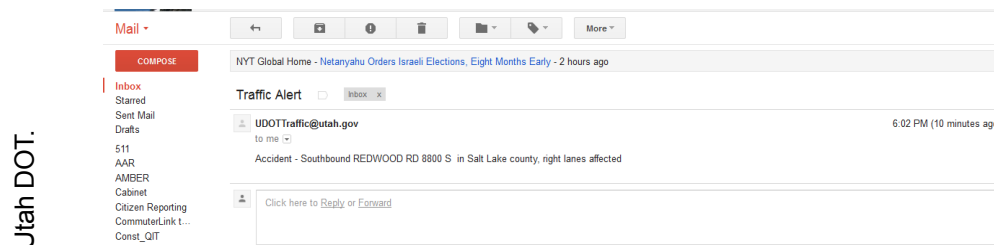
An email alert from the UDOT Traffic website

- UDOT Traffic Twitter Account – Launched in June 2011, the UDOT Traffic Twitter account disseminates traveler information regarding crashes, weather events, and special event traffic management. UDOT's @UtahDOT Twitter account hosts information about working for UDOT, seatbelt safety, etc. It is staffed 24 hours a day, seven days a week. Currently, there are 3400 followers, many of which are local media. It can be estimated based on re-tweets that UDOT Traffic Twitter messages can reach nearly 100,000 followers with each tweet.

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- Utah 511 Traveler Information System – Utah was one of the first states to launch a 511 traveler information phone line. Total calls since its launch are nearly 4,500,000 with a majority of the public calling when there is a severe winter storm or large special event. The average call is 1.2 minutes and, depending on the month, between 43% and 74% of callers select the "Traffic and Road Conditions" menu option.

- UDOT Traffic Application (App) for Mobile Devices – In a continuing effort to diversify the types of traveler information, UDOT launched the UDOT Traffic app in November 2011. Since its launch, the app has been downloaded over 92,000 times. The app is available for free download on any Android or Apple device. The app hosts the same information as the UDOT Traffic website, but is available in the palm of a hand. It is critical that users do not interact with the app while they are driving. This criterion is included in the acceptance policy that each user must agree with prior to using the app.

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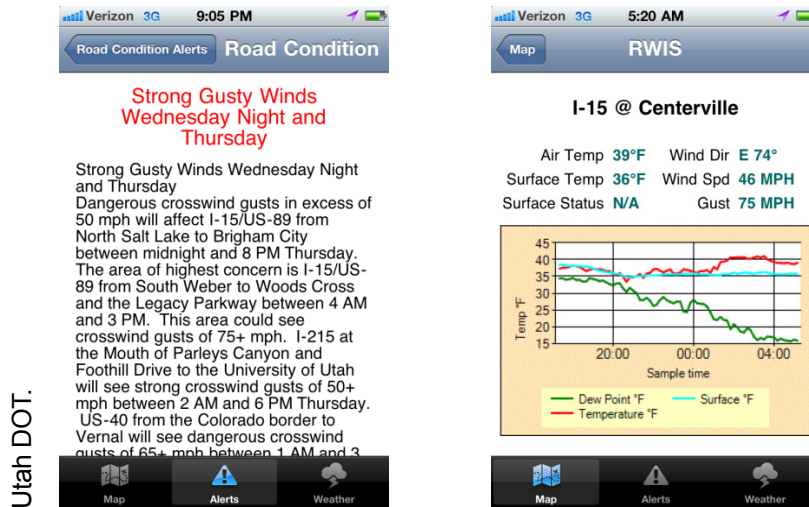
Traveler Information Output for November 30 - December 1, 2011 Wind Storm

The UDOT Traffic App is useful because of the number of cellular phones in use in Utah as well as the depth of the cellular network. Wyoming DOT chose to have their Citizen Reporters submit information by phone/landline to their Traffic Operations Center operators rather than using an app because of the rural nature of their state and the limited cellular coverage. However, Utah has a more developed cellular network even in the rural parts of the state. The four most used cellular carriers in Utah are Verizon, Sprint, AT&T, T-Mobile and Cricket. See maps below for a description.

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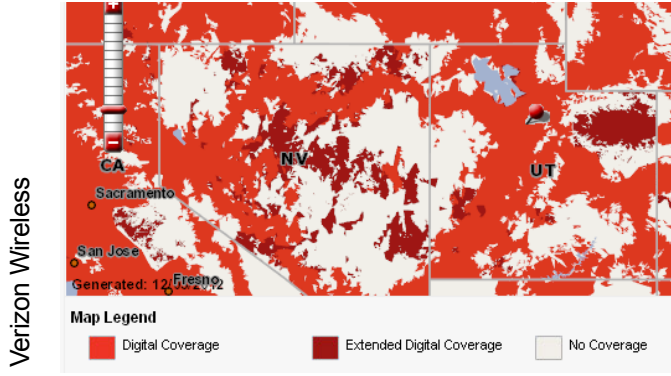
Verizon Wireless

Verizon Wireless Coverage
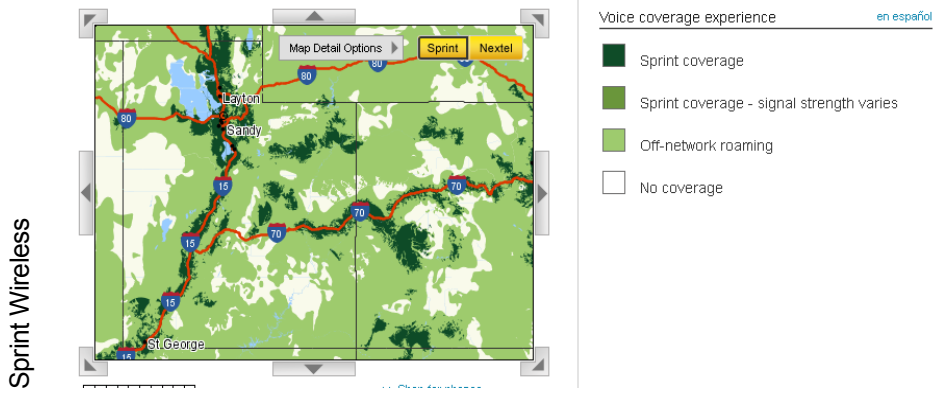
Sprint Wireless

Sprint Wireless Coverage

AT&T Wireless

AT&T Wireless Coverage

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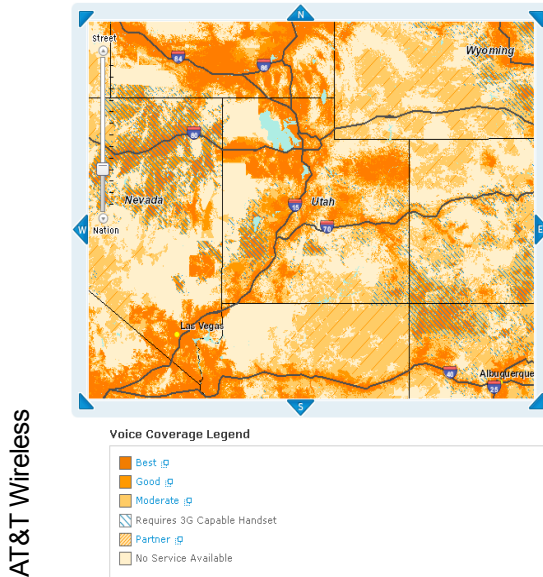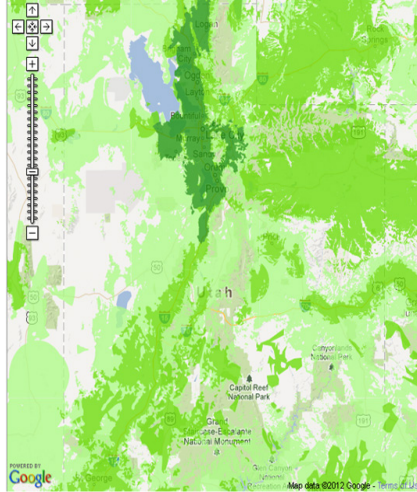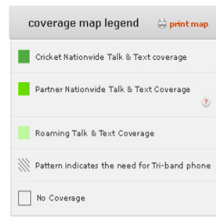
Cricket Wireless Coverage
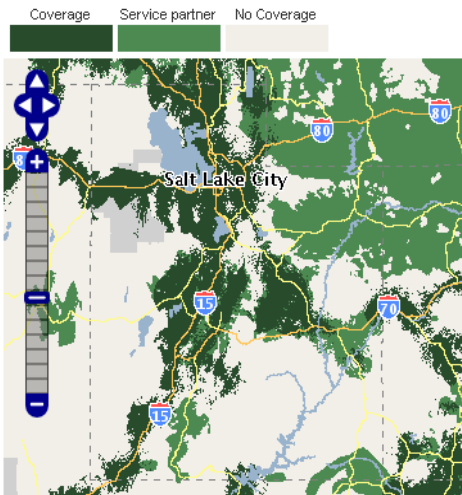
T-Mobile Wireless Coverage

- Highway Advisory Radio (HAR) System – UDOT has a traditional Highway Advisory Radio (HAR) network deployed through the most populated counties in the state (Salt Lake, Utah, Box Elder, Davis and Weber counties). The system is using aging technology and is not widely used, as it is somewhat unreliable. The 511 traveler information phone line in conjunction with the Variable Message Signs (VMS) are often used in place of the HAR. New technology has been deployed on HAR units that operate in Big and Little Cottonwood canyons that use a text to speech capability. This new technology has made the HAR units easier to use and verify messages. It is unknown if the same technology is planned to be installed on the other HAR units.

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Justification for Changes

The existing 6-hour forecast increments cover wide swaths of time and do not allow for useful detail. Weather can change rapidly in Utah, and a 6-hour summary of expected weather usually does not accurately describe when the hazards are going to start or stop impacting roadways. The enhanced forecasting component decreases the time increments so that more detail can be inserted into the forecast. The enhanced forecasting component increases the frequency and extent of road weather forecasts to 3-hour increments spanning 24 hours into the future. With greater TI Meteorologist resources, UDOT will include six additional state routes of significance (US-191, US-89, US-189, SR-20, SR-210 and SR-190) because they are important commuter routes, winter recreation routes or potential detour routes during adverse weather. Therefore, heavily traveled wintertime routes will have forecast weather information. Because UDOT has an existing wide-reaching road weather reporting program that most State Departments of Transportation do not have, travelers in Utah expect clear and useful road weather reports on significant wintertime routes. The addition of the six routes helps to meet this expectation. This enhanced forecasting model builds a foundation for even further expansion of the forecast to additional roads and greater forecast extent in future winter seasons.

The needs for accurate road condition reporting have evolved with technology and public access to information. Although plow operators are required to report conditions twice daily, other tasks in the field often take precedence, and there is likely some resistance to reporting conditions which may reflect poorly on their performance. Oftentimes, reports would not be updated as conditions changed, and travelers would be left with inaccurate data. Sometimes this would lead them into unforeseen hazardous conditions, which the TOC learned from public feedback on app ratings and on Twitter. Last winter, UDOT's sole TI Meteorologist began updating road condition reports using available data resources from the TOC – radar, weather model output, traffic cameras and RWIS – but limitations of the observation network in Utah did not allow for the same quality of assessment that a human in the field could provide. Also, because of work limitations, updating conditions from the TOC was not possible 24 hours per day. Increased staff and citizen reporting will help to mitigate this problem.

Forecasts will be displayed on the traffic maps located on the UDOT Traffic website and smartphone app. The FHWA Messaging Guidelines will be considered when updates to the UDOT website and smartphone application are revised in terms of message formats and guidance. In addition to the map products, greater forecast detail and recommended actions will be available in the Road Weather Alerts portion of the website and app, when completed.

TI Meteorologist coverage will be supplied by UDOT's weather services provider. This staffing plan does not provide 24 hour coverage. As noted in the evaluation plan, the additional TI Meteorologists hired will log their working hours and will be available to provide consistent coverage during winter storms. This will allow for the TATS data and Citizen Reports to be fully utilized. If work shifts do not overlap, there will be 7 hours per day where the Traveler Information Meteorologist will not be covered. It is likely that shifts will overlap slightly during storms especially if the urban corridor is being impacted during a commute. Overlapping shifts will allow for the 2 hour update (as noted in the evaluation plan) frequency during these storms without sacrificing detail elsewhere. With this staffing plan, oversight of incoming road condition data will occur, and, if stale or incorrect, can be corrected by the TI meteorologist. Consequently, active quality control and updating of weather information will occur in real-time and will ensure information going to the public is accurate and timely.

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Because a weather forecast starts with current weather information to develop forecasts, better field data also means better forecasts. Utah is a state of data-scarce regions, complex terrain and micro-climates. Radar coverage is non-existent through the center of the state, and the scale of the micro-climates in complex terrain falls below the resolution of operational weather models. The citizen reports will help the forecaster to fill in the gaps and tune model data to fit the micro-climatic environment. An evaluation measure will include the number of reporters per route. The goal is to have at least eight reporters per route, and it will likely not detract from this project or the final result if this goal is not realized in the first year or two of the Citizen Reporting Program. The overall effect is an improved understanding of and forecasting for the road weather in Utah. When reports are received from the trained Citizen Reporters, those reports will be posted directly on the UDOT Traffic public facing website with quality control from a TI Meteorologist after the report has been broadcast. The information will be useful for the TI Meteorologists as well as the public because the information obtained would not be available without the Citizen Reporters.

Concept for the Proposed System

The proposed system is an enhancement to the road weather information already provided by UDOT in that it:

- Increases the frequency and extent of the road weather and traveler impact forecasts
- Fills gaps in various routes, particularly in rural areas with limited resources
- Adds additional routes of significance to those already receiving a forecast
- Improves current road condition information for travelers on the road

UDOT will develop a reporting portion of the UDOT Traffic app through which citizen reporters can provide information on a given route. GPS location or a manually-entered location field may be employed. Reports will be quality checked during storms by meteorologists in the TOC, and updated as needed. The reports received by citizen reporters will be quality checked in the same manner as the current TATS reports. When a UDOT plow driver submits a road condition through the UDOT web reporting portal, that report is automatically sent to the public facing UDOT website for use by the public. The citizen reports will act in the same manner – they will automatically be sent to the public facing UDOT website and smartphone application. In the event that a report is incorrect or out of date, a TI meteorologist can and will change the condition to report a more accurate condition. Prior to allowing any Citizen Reporters to assist with road condition reporting, they will be required to attend a training seminar to learn how to properly report conditions. UDOT has taken every means necessary to ensure the reports will be as correct and updated as possible. As noted in the evaluation plan, it is assumed that once trained, the Citizen Reporters selected to participate in the program will be as accurate, if not more accurate, than the current TATS reporting plow drivers.

Road Weather Sources

The Citizen Reporting data gathered is intended to supplement current reporting mechanisms in order to give a more complete picture of Utah's roadways during storm events and during normal winter driving.

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UDOT Weather Operations Program Data Input Sources
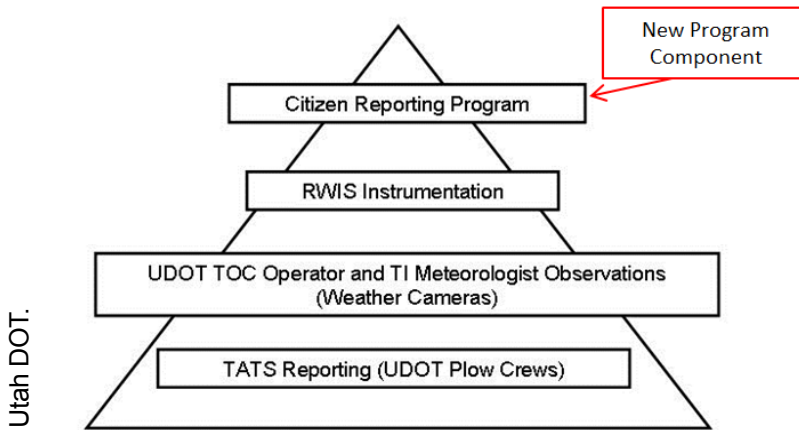
Diagram shows UDOT's use of weather data in creating forecasts and Nowcasts.

Road Weather Data Aggregator Approach

Aggregation of the Citizen Reporting data will occur seamlessly. The data will be delivered to the same location as the existing TATS reporting segments gathered by UDOT plow crews. In addition to a training program for the Citizen Reporters, there will be additional oversight from the TI Meteorologist in the event that a Citizen Reported segment is erroneously reported and is inaccurate. This method of quality control will be the same method currently utilized for the TATS segment reporting. Utah drivers comment frequently on the timeliness of the report; however, it is infrequently reported that a road report submitted by a plow driver is inaccurate. Since UDOT plow drivers have not been trained in the same manner that the Citizen Reporters will be, it is likely the reports from the Citizen Reporters will be more accurate and will require less effort on quality control. In the unlikely event that a Citizen Reporter consistently reports inaccurate information, road report submissions from that reporter can be excluded from the public facing reports. The Citizen Reporting data is intended to be supplemental to the overall data gathering and at this time is not meant to replace any current reporting mechanisms.

Road Weather Forecasting

The enhanced forecasting component increases the frequency and extent of road weather forecasts to 3-hour increments spanning 24 hours into the future. The spatial extent will also increase, as 6 additional state routes of significance will be added. These routes, US-191, US-89, US-189, SR-20, SR-210 and SR-190, were chosen because they are important commuter routes, winter recreation routes or potential detour routes during adverse weather.

Three TI Meteorologist forecaster shifts will be interspersed throughout the week, covering all daytime and most overnight hours, weekdays and weekends. During hazardous weather events, shifts will cluster around the event, allowing for full-time coverage of the event. Winter season manpower will total 3,100 hours. This estimate assumes 120 hours of work per week from November to April. Manpower will reduce to 20 hours per week during the summer season – May to October. The work will be supplied by UDOT's weather services provider. Forecaster duties will follow what is already performed, but forecasts will be able to be updated.

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Traveler Information Dissemination

Forecasts will be displayed on the traffic maps located on the UDOT Traffic website, the 511 Traveler Information phone line and smartphone app. The FHWA Messaging Guidelines will be considered when updates to the UDOT website and smartphone application are revised. In addition to the map products, greater forecast detail and recommended actions will be available in the Road Weather Alerts portion of the website and app.

Citizen Reporting

UDOT will develop a reporting portion of the UDOT Traffic app through which citizen reporters can provide information on a given route. Reports will be quality checked during storms by meteorologists in the TOC, and updated as needed. As mentioned earlier in this document, the initial Citizen Reporter group will begin with a small sample in this project, and the end-goal is to enlist 8-10 citizen reporters per route segment with a total of 800-1000 reporters. The long term goal of adding Citizen Reporters to UDOT's weather operations road reporting is to supplement current condition reporting on segments where drivers are already traveling. Many of the segments selected for the pilot testing are areas where there is no infrastructure to install an RWIS or traffic camera, even though the route is a busy winter route. The TI Meteorologist staff carefully selected test segments based on weather patterns and adjacent routes that are currently reported. If the pilot is successful, the long term goal will be to add additional routes for which Citizen Reporters will provide information. The pilot season will be utilizing a total of approximately 100 reporters. Those reporters will be selected from each of UDOT's four regions, the TOC, and UDOT's central office.

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UDOT Citizen Reporting Program Communications Diagram
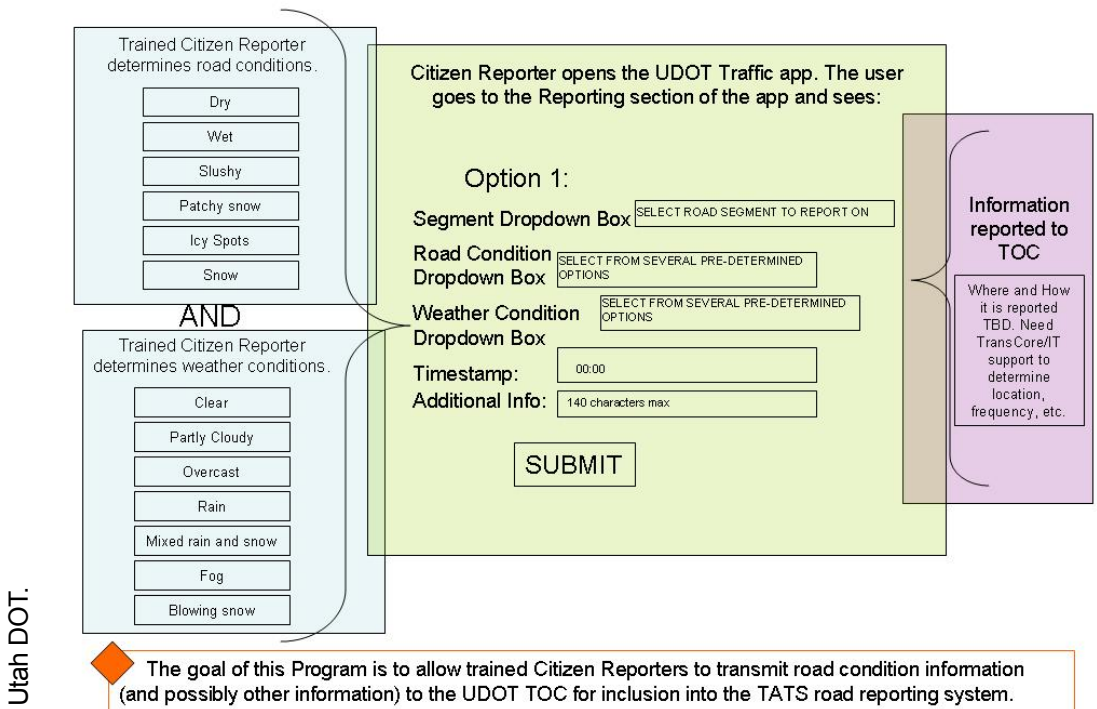
Information Flow Diagram for Citizen Reporting Information. This diagram represents the initial approach however the final product that will be used to collect Citizen Reporter data will vary slightly. More information on the final reporting tool will be included in the Evaluation Plan.

Integration of Citizen Reporting into forecasting process

Current condition reports from citizen reporters will be incorporated into the same web-based software that already manages the incoming plow driver reports. For additional explanation on the information flow, see the diagram above. In order for the data received from the Citizen Reporters to be valuable, it has to be seamlessly inserted into the current system used by the TI Meteorologists. If the data creates a high level of effort required to interpret and use the data, it will not be valuable, as the UDOT Weather Operations group does not have the necessary staff.

The existing web-based TATS software is accessible through any internet connection and allows plow drivers to report current road conditions. The system is operational only in the winter months (October – April).

The TI Meteorologists interacting with the existing program will have the ability to override any incoming report or update any stale information. The TI Meteorologist can also check a box to indicate if a report submitted by the citizen reporter is not accurate. Citizen reporter information will provide improved observational granularity for the TI Meteorologists by more frequent reports being received.

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Operational Scenarios

An operational scenario is described below illustrating how the new system components can improve UDOT road weather forecasting and travel during adverse weather from three different points of view.

Utah DOT Traffic Operations Center View

Media has been reporting a significant snow event tomorrow early afternoon but as with most media reports they are not focused on road weather and are very general. The TI Meteorologist is also looking at the models and sees that snow is indeed in the forecast along the Wasatch Front but based on his experience, he feels that snow is not going to affect the roads until around 4:00 pm, with highest impacts in Weber County. He creates a road weather impact forecast indicating that road conditions are expected to worsen in the 3-6 pm timeframe due to snow accumulating on roads faster than plow crews can mitigate it.

As the event nears, he updates his forecast but both the citizen reports and the weather models seem to indicate that the forecast is on track. At 3:30, he starts seeing citizen reports come in with worsening conditions. As a courtesy, he also lets the TOC operators and the maintenance meteorologists know that citizen reports are indicating wet and icy roadways so that they can take the necessary actions for their groups.

Citizen Reporter View

After undergoing training by Utah DOT, UDOT employee X has been a citizen reporter for the traveler information program for the past three months. His job in the UDOT region has him on the move often inspecting bridges or ITS devices in the field. Today he has been assigned to conduct an inspection at several facilities in Weber County. As he begins his day, he notes that it is a crisp clear Utah morning as he drives to his first facility. When he gets to his first facility, he has a few minutes before his meeting, so he logs on to the mobile app and notes that the sections he traveled on were dry.

After a couple of visits to other facilities, he is traveling back home to Ogden around 3:00 pm. It has started to snow, but as he drives along the roadway, he notes that there is only wet pavement and occasional areas of slush. When he reaches home around 3:30 pm, he opens the mobile app and reports conditions on the segments he's traveled in, noting that pavements are started to get wet and slushy in patches.

Being a traffic geek, he logs on his computer at 3:45 to check the UDOT website and he sees that the segments he reported on are now noted as wet and slushy in patches. He is happy to see that his reports now play a vital role in informing travelers in Utah of road conditions.

Utah Traveler View

A woman who lives Weber County is watching the local news and sees that snow is in the forecast for tomorrow afternoon. The broadcast meteorologist reports that a cold front will pass through northern Utah between 1 and 5 pm, bringing a couple inches of snow and gusty winds. Since this is most of the afternoon, she is conflicted on whether to go to work early, to give herself the option to leave early. Wanting more information on how the front will impact her evening commute within the Salt Lake Valley the next day, the woman checks the UDOT Traffic website. She uses the website frequently for incidents and congestion reports on her commute but usually does not rely on the weather side.

However, today she clicks on the website and sees that there are 3-hour forecasts for her work routes going out to 24 hours. This makes sense to her as she knows how quickly weather changes in her part of Utah. In addition, she is able to look at the current conditions on her routes. She clicks through

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the forecasts and notes that rain will start in Weber County around 3:00 pm, and quickly change to snow. Hazardous road conditions and travel impacts are expected by 4:00 pm. Knowing that the road conditions are not going to worsen until 4:00 pm, she goes to bed early so that she can start work early the next morning, giving her the chance to leave work ahead of the storm.

At 1:00 pm before her staff meeting, she checks the 3-hour forecasts on the UDOT Traffic website and sees that the weather event is proceeding as forecast. The forecast is still on track. At the conclusion of her meeting at 3:30 pm, she checks the mobile application to see if there are new reported conditions in Weber County. She sees that road segments are just starting to be reported as wet roads turning to slushy roads. She leaves work just then to avoid getting stuck in poor driving conditions or gridlock due to the storm. She makes it home at 4:00, just as snow is starting to accumulate on her driveway, thanks to her proactive use of UDOT's information.

Summary of Impacts

Upon implementing this project, the accuracy and timeliness of weather-related traveler information will be improved. The resolution of road weather observations and road weather forecasts will be increased. Specifically, this project will enhance reports by:

- Generating road weather reports at a minimum of every 2 hours during adverse road weather events for some or all of the TATS segments.
- Providing better coverage on rural roadways
- Supporting SAFETEA-LU 1201 by providing real-time reporting on roads throughout the state
- Actively quality controlling reports using staff meteorologists
- Providing quality assurance through training and reporter selection process
- Providing more information at a fraction of the cost of other alternatives
- Directly improving forecasts through increased frequency (3 hr increments, out for 24 hours)
- Indirectly improving forecasts, because meteorologists will have better field data

Enhanced forecasting will start November 2012, and run through April 2013. During summer 2013, forecasting will continue as needed, and the winter 2012/13 season will be reviewed. The project is expected to continue annually.

If the project is properly implemented, the workload for the TI Meteorologists will not increase significantly. The Citizen Reporter data gathered will need to be reviewed; however, the training program will help to reduce erroneous reports. Proper selection of reporters will also minimize incorrect data. This project will increase the workload for the UDOT Traveler Information Manager; however, the increase will most likely be seasonal. Other duties such as training reporters and managing the reporter database will be sporadic and year-long. There will be some travel required within the state of Utah to train Citizen Reporters; however, this travel should be minimal. A majority of the workload increase will be realized during the initial implementation phase of the Citizen Reporting project.

As the project successes are realized, it is likely that an organizational impact will be that more UDOT staff are contacting the Weather Operations staff for weather information. There will be more visibility for UDOT management about the program's mission and goals.

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Analysis of Proposed System

The first season of the Citizen Reporting project is considered Phase I, with selected UDOT employees acting as trained reporters. Once the Citizen Reporting program is fully launched the goal is to gather 12 reports daily on each UDOT road segment throughout the state. The next phase will begin the following season, and will incorporate public observations. It is likely that additional enhancements and modifications will be needed to the smartphone reporting component once it is launched and the Citizen Reporters have an opportunity to interact with it. An analysis of the Citizen Reporting component will be very valuable, as the overall effectiveness and cost/benefit of the program is still undetermined. However, the positive feedback UDOT received from WYDOT indicates that the program will be a success and will provide valuable, measurable data for UDOT's Weather Operations Program.

The TI Meteorologists will provide more consistent coverage of public facing weather reports. Currently, the manpower provided for this function is inadequate given the nature of weather operations. Additional forecasters will allow for more even coverage and more frequently updated public weather information.

Messaging for events that will affect traffic (winter storms, special events, construction projects, large incidents, etc.) is a critical component of the UDOT Traffic Operations Center. Traffic patterns often act as a measure of effectiveness for how well UDOT succeeded in disseminating the message to travelers. For winter storms and general winter travel, an expected traffic response would be for travelers to possibly alter their travel patterns by leaving ahead of the storm or waiting until the bulk of the storm passes to travel. Also, travelers may change their routes and take a less affected route if their travel is critical.

Project Evaluation

This Concept of Operations document is written to correspond directly with the project Evaluation Plan. The plan outlines the following 5 hypotheses and the methodology by which each will be tested:

- Citizen reports will help to fill observational gaps, spatially and temporally.
- Citizen reporters will provide accurate information to UDOT.
- Internal UDOT operations will benefit from increased road condition reports and forecasts.
- The traveling public will make more informed decisions based on the new information.
- The traveling public will perceive a benefit from the enhanced information.

Data collection will occur throughout the season, and evaluation testing will commence during spring 2013. The evaluation will help to guide program development in future seasons.

Notes

List of Acronyms and abbreviations:

- UDOT – Utah Department of Transportation
- WYDOT – Wyoming Department of Transportation
- TOC – Traffic Operations Center

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- WRTM – Weather Responsive Traffic Management

- TI – Traveler Information

- TI Met – Traveler Information Meteorologist

- RWIS – Road Weather Information System

- TATS – Traveler Advisory Telephone System

- UCAR – University Corporation for Atmospheric Research

- AAR – After Action Report

- HAR – Highway Advisory Radio

- VMS – Variable Message Signs

List of any terms or definitions:

- I-80 Winter Operations Coalition – Mission is t*o provide better and more comprehensive I-80 corridor conditions information to both transportation agencies and to travelers; To build on existing multi-state coordination efforts on I-80 and expand to include general road conditions information, consistent corridor-wide traveler information, proactive traffic management strategies, coordinated maintenance operations and potentially shared use of infrastructure near state boundaries; and to leverage state resources and tools to implement innovative solutions for winter operations as well as day-to-day corridor management.*

- *"Nowcasts" – Nowcast weather information is not a forecasted prediction of what weather will occur, but rather a weather report of what is happening right now or what will happen in the near future.*

- *UCAR* – The University Corporation for Atmospheric Research is a hub for research, education, and public outreach for the atmospheric and related Earth sciences community. The organization provides grants to fund scientific endeavors.

- *TATS* – UDOT's Traveler Advisory Telephone System is an existing weather and road condition reporting system used by plow crews in the field. TATS segments are defined by the areas of responsibility for the plow crews. The stated expectation is that segments will be updated twice daily – morning and afternoon – and as conditions change.

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APPENDIX B – Utah DOT Wx-TINFO System Evaluation Plan

Introduction

Purpose of this Document

The purpose of this document is to describe the evaluation strategy of the Weather Responsive Traffic Management (WRTM) Weather-related Traveler Information (Wx-TINFO) Project implementation at Utah Department of Transportation (UDOT). It will serve as a tool to guide program assessment. The document outlines five evaluation hypotheses, and details the methodology by which each will be tested, including data to be used. Data collection will occur throughout the season, and evaluation testing will commence during spring 2013.

Project Description

Current and forecast weather conditions are a critical part of traveler information in Utah. Utah has many high mountain passes and rural routes that frequently experience hazardous winter weather, and accurate road condition information for these routes is vital for traveler safety and route planning. Additionally, almost all of Utah's non-recurring urban congestion occurs as a result of weather. Following large winter storms, UDOT holds After Action Report (AAR) meetings to quantify the delay caused by the event, UDOT's messaging, and other storm factors. For several of these storms, UDOT has data that can support how the messaging and creation of situational awareness has an impact on traveler decisions. When provided with accurate weather information, travelers can make changes in their travel behavior, plans, or preparedness thus possibly reducing the potential for congestion and weather-related crashes.

Currently, the Utah Department of Transportation posts current and forecast conditions on the UDOT Traffic website, 511 Traveler Information phone line and the UDOT Traffic smartphone application. At this time, the reports are of fairly low spatial and temporal resolution. The increased ability for travelers using the mobile app to access real time data has spurred an effort to enhance the weather data available to travelers pre-trip and en route. Since its launch, the UDOT Traffic app has been downloaded over 78,000 times. It has been an excellent resource for distributing traveler information to the public. Because of its heavy usage, data on the app is more highly visible than ever, which puts more demand on real time, up to date, and accurate data.

The Citizen Reporting component of this project enlists selected and trained personnel to report on current road conditions along specific roadway segments across Utah. The reporters could be UDOT employees, law enforcement, truck drivers, plow drivers, experienced commuters, or other volunteers. Citizen Reporters would be trained yearly on what to report on and how to provide accurate road weather reports. While initially starting with a small sample in this project, the end-goal is to enlist 8-10 citizen reporters per route segment with a total of 800-1000 reporters. The long term goal of adding Citizen Reporters to UDOT's weather operations road reporting is to supplement current condition reporting on segments where drivers are already traveling. Many of the segments selected for the pilot testing are areas where there is no infrastructure to install an RWIS or traffic camera; however, the route is a busy winter route. The TI Meteorologist staff carefully selected test segments based on weather patterns and adjacent routes that are currently reported. The citizen reporting component of this project is designed to enhance UDOT's coverage of road weather reporting on under-reported segments throughout the state of Utah. If the first season implementing this concept is successful, the long term goal will be to add additional routes and expand the number of citizen

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reporters. The first season will be utilizing a total of approximately 100 reporters. Those reporters will be selected from each of UDOT's four regions, the TOC, and UDOT's central office.

The Traveler Information Meteorologist (TI Met) component of this project will hire two additional meteorologists based at the UDOT Traffic Operations Center (TOC). The focus of the additional meteorologists will be to produce road weather impact forecasts for travelers. To do this, they will utilize citizen field observations, RWIS, radar and satellite data and weather models to produce road-specific forecasts. They will relate this weather information to the public by describing the impact that the weather will have on road conditions and traffic. They will also serve as TOC-based quality control for incoming road condition reports from citizen reporters.

Objectives of Evaluation

The analyses outlined in this plan (section II) were designed to evaluate the following:

- Success of citizen reporting at filling existing gaps in weather observations along roads in Utah

- Timeliness and accuracy of citizen reports

- How or whether the enhanced weather forecasting and road condition reporting improves internal UDOT operations

- Whether the traveling public finds the enhanced weather information useful and how the information was used during the 2012/13 winter season

- How or whether traffic patterns can show a public response to road weather forecasts prior to high-impact storms

The evaluation will also help to guide program development going forward. Season 2012/13 will be the first year of UDOT's citizen reporting implementation, and the evaluation will help to guide distribution of reporters (number and location) in following seasons. Feedback on public usage of the information will direct how to better work together with partner agencies, such as local media and the National Weather Service (NWS) branch in Salt Lake City.

Document Organization

Section I provides background, purpose and objectives of Utah's Wx-TINFO program and subsequent program evaluation. Section II outlines the evaluation approach, which includes detailed descriptions of how to test each of five project hypotheses. Section III lists challenges and constraints inherent in evaluating the program, as well as strategies to mitigate them. Section IV outlines the evaluation schedule and provides an itemized action plan for evaluation preparation.

Evaluation Approach

Table B-1 identifies five hypotheses that will be tested during the project evaluation. Table B-1 also outlines the tools for testing each: measures of effectiveness (MOEs) to guide analysis, data needed to complete the analysis, and the analysis methodology. The subsections below Table B-1 provide some background for each hypothesis and describe the testing methodology in detail. It is important to note that for seasonal analyses, data should be restricted to December 1 to March 31, and the analyses will be completed during April. For most of the hypotheses, analyses may be done for a single storm or half-way through the season. Storm-only analyses will improve after-action reviews for major storm events, and more frequent analyses will help to make mid-season adjustments where needed.

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Unanticipated Problems/Benefits

In addition to the analyses outlined in Table B-1, personnel in the TOC will keep a log in which they will note any other problems or benefits encountered throughout the course of the season, which will be important to note for future development. Potential problems may be software issues that arise, manpower requirements for keeping the information up-to-date, feedback from citizen reporters, cell coverage problems, etc. The log will be accessible to all TOC employees and will be reviewed at the end of the season and used for future planning.

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Table B-1. Evaluation approach.

Hypothesis	Measures of Effectiveness	Data Needed	Analysis
1 Citizen reports will help to fill observational gaps, spatially and temporally.	Outputs: a. Citizen reporting added to road segments in need of observation b. Time delay between observing road conditions and submitting a report (ob-submit delay) c. Time difference between report (observation) updates (update time gap) d. Temporal nature of reports per segment e. Individual reporter performance	a. TATS segments targeted for citizen reporting in order to fill gaps in observation; Segments covered by assigned citizen reporters b. For each report, observation time and submission time c. For each road segment, report observation times d. Number of citizen reporters assigned to each segment e. Timestamp of reports for each reporter	a. % targeted segments covered by assigned citizen reporters b. Calculate delay between observation and submission times; proportion of ob-submit delays in various interval categories c. Calculate time gap between report updates per segment; proportion of update gaps in various interval categories d. Per segment: # reporters, average ob-submit delay, update gap distribution e. Per reporter: assigned segments, frequency of reporting per day, usual time of reporting
2 Citizen reporters will provide accurate information to UDOT.	Outputs: a. Citizen reports flagged as inaccurate and removed by TI meteorologist b. Enrolled citizen reporters flagged as unreliable	a. Large sample size of incoming citizen reports, QC'd in realtime; tally of inaccuracies found; nature of inaccuracies b. TI manager should keep a log of reporters warned or removed from program	a. Of all incoming citizen reports, fraction flagged as inaccurate; log nature of inaccuracies b. Number citizen reporters warned or cut from reporting program
3 Internal UDOT operations will benefit from increased road condition reports and forecasts.	Outputs: UDOT personnel access to higher resolution road condition and forecast updates. Outcomes: a. Improved traffic operator situational awareness for performing job duties (e.g., posting VMS) b. Improved meteorologists' ability to produce and verify forecasts c. TMD managers making well-informed decisions and learning from post-storm reviews d. Other UDOT groups using information to improve performance	a, b, c. Survey responses from operators, forecasters, managers d. Feedback from managers in other UDOT divisions	- Frequency personnel refer to weather forecast/road condition information on UDOT Traffc and for what purposes - Whether 2012/13 information was helpful/more helpful than in previous years - Open-ended responses of opinions and examples of how information was used to improve job performance - Examples from other UDOT Divisions on whether or how they used the information

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Hypothesis	Measures of Effectiveness	Data Needed	Analysis
4 The traveling public will make more informed decisions based on the new information.	Outputs: Traveler decision-making before and during storms Outcomes: a. Relative to non-storm day, more traffic before or after storms; travelers completing trips prior to storms or delaying travel until after storms b. Increased public usage of road weather information prior to event. c. Changes in travel behavior (delay trip, cancel trip, change route or mode, be more prepared, etc.)	a. Traffic volume or vehicle miles traveled data before, during, after storm events (PeMS) b. Page views of road weather page at 20-min intervals, restricted to before and during and event c. Survey or focus group	a. Plot traffic volume or vehicle miles traveled through duration of an event; include prior day if daylong event; compare to travel on same day(s) of week in prior/non-storm years b. Plot page views before & through event on same chart as (a) c. Survey or focus group assessing public's decision-making given their access to enhanced weather information. - users changing departure time, route choice, mode of transport as a result of information - users making pre-trip preparations in response to information - users more likely to monitor weather conditions vs. previous seasons
5 The traveling public will perceive a benefit from the enhanced information.	Outcomes: a. Traveler awareness of and satisfaction with UDOT Traffic weather forecast information will increase b. Increase in positive, decrease in negative public comments on weather info c. Increase in usage of road weather information on website (road weather page, RWP; road weather alert, RWA) d. Increase in UDOT Traffic app downloads and usage	a. NWS/UDOT/UofU survey results b. 511, app, email feedback logs from winters 2010/11, 2011/12 and 2012/13, as available; weather-related marked positive or negative c. Page views of RWP & RWA, from 2011/12 and 2012/13 # storm days d. App downloads, page views # storm days	a. External effort to this evaluation, survey will find out: % SLC drivers using UDOT's information and other sources of information; % satisfied with UDOT Traffic info and with other sources of info b. % occurrence of negative/positive weather-related 511, app, email user comments from 2010/11, 2011/12 and compare to 2012/13 c. All data normalized by storminess (# storm days) Change in total (normalized) RWP & RWA usage from 2011/12 to 2012/13; rate of change in usage per month; average monthly usage over season and change from 2011/12 to 2012/13 d. % increase of app downloads (cumulative) from 2011/12 to 2012/13; trend of downloads over 2012/13 season Change in total (normalized by storm days) usage from 2011/12 to 2012/13; rate of change in usage per month; average monthly usage over season and change from 2011/12 to 2012/13

Source: Utah DOT

Hypothesis 1: Citizen reports will help to fill observational gaps, spatially and temporally.

Because Utah is a state with large gaps in weather observation, one objective of the project is to utilize citizen reporting to fill critical observation gaps with travelers' reports from the roads. Current weather observation technologies include radar, RWIS and cameras. Even if present on a section of road, each technology has limits for traveler information applications. Radar is not widely interpretable by the public, and it cannot directly indicate road conditions without ancillary information. Additionally, radar coverage is poor through much of the central part of the state, through which major US routes and interstates traverse mountainous terrain (see Fig 1A in Appendix A). RWIS sites provide point measurement, in comparison with spatial measurement, and may not represent a larger area near the site. Also, they are more helpful to the general public when the raw data can be interpreted. Cameras are also site-specific and are not useful at night or in low visibility weather. Therefore, there are critical gaps in useful weather observation which have been targeted by UDOT's Traffic Management Division and are listed in Appendix A.

Analysis for (a) of Hypothesis 1 will track UDOT's success in assigning citizen reporters to the targeted segments. Only the segments with assigned citizen reporters will be counted, although there will be segments which receive reports from citizens not assigned to them; the critical measure for this analysis is reliable observation. There are 62 targeted segments in need of citizen reporting to fill observation gaps (Table 1A). Of these 62, those which have at least one dedicated citizen reporter will be counted, and the percentage of segments with citizen reports will be calculated. Because ultimately UDOT will want to have citizen reporters on every route in the state, it will also be useful to track the percentage of remaining statewide segments filled. Table B-2 can be used to record the results from the analysis.

Table B-2. Analysis for Hypothesis 1.

	# segments	# of these segments with citizen reporters	% segments with citizen reports
Targeted segments	62	_____	_____%
Remaining statewide segments	80	_____	_____%

Source: Utah DOT

Observation coverage is crucial not only in space, but also in time. In order to quantify timeliness of citizen reported information, the following will be measured: time delay from when the road weather condition was observed to when the report was submitted (herein referred to as ob-submit delay, measure b) and the amount of time between citizen reports per segment (herein referred to as update time gap, measure c). Ob-submit delay, (b), occurs because the app gives the user the ability to enter a report minutes or hours after the road condition is viewed. This feature was added as a safety measure, so that reporters could log reports once they arrived at their destination. Tracking ob-submit delays will help UDOT measure the freshness of incoming reports. Also related to timeliness, UDOT set a goal to have citizen reports at least every 2 hours per segment, and so, for (c), the analysis will test how often that goal was reached, or whether there were many update times much larger than 2 hours. The update time gap will be calculated from the observation time, not the submission time.

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The ob-submit delay will use data logged from the citizen reporting app. When the reporter enters their report, they can specify the time they actually observed the road condition, in the event they are submitting the report minutes or hours after they observed it. For each incoming report, the observation and submission times will be logged. For the analysis, a simple program can be written that calculates observation-to-submission time difference for all reports over the season, creates a data table of ob-submit delays, and then tallies how often the delays fall into one of 5 categories, listed in Table B-3. The proportion of delay times that fall into each of the categories is the category's tally divided by the sum of the tallies and expressed as a percentage. For the freshest reports, there should be a greater proportion of ob-submit delay times closer to 0 minutes. For safety considerations, as mentioned above, times greater than 0 minutes are acceptable for reporting. Additionally, for future planning, it would be helpful to note the specific route segments that have the largest ob-submit delays. Delays may be large on very long rural segments.

Table B-3. Analysis for Hypothesis 2b.

Ob-submit Delay Category	Tally	Proportion
0 minutes		%
>0 and ≤ 15 min		%
> 15 and ≤ 30 min		%
> 30 and ≤ 60 min		%
> 1 hour		%
Sum of tallies		

Source: Utah DOT

The update time gap will also use data logged from the citizen reporting app, but on a per segment basis. For each segment (or a selection of segments), the update times of the citizen, TOC and plow driver reports will be logged. Citizen reporting times (specifically, observation time) should be isolated for this analysis. As with the ob-submit delay analysis, data tables can be created using a program that calculates the time between reports, and tallies the number of times this time gap falls into one of six categories, listed in Table B-4. Because each segment will undergo this analysis, the segments will be comparable, and UDOT can use the results to allocate resources appropriately in future seasons. With increased citizen reporter participation and a more varied citizen group, it is assumed that there will be more occurrences of updates within 2 hours of one another.

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Table B-4. Analysis for Hypothesis 2c.

Road Segment: _____		
Update Gap Category	**Tally**	**Proportion**
≤ 2 hours		%
> 2 and ≤ 4 hours		%
> 4 and ≤ 6 hours		%
> 6 and ≤ 12 hours		%
> 12 and ≤ 24 hours		%
> 24 hours		%
Sum of tallies		

Source: Utah DOT

Measure (d) of Hypothesis 1 will help UDOT evaluate the temporal coverage of reports per segment by combining results from (a), (b) and (c). For each segment, a summary of coverage will be created, which will include the number of citizen reporters assigned to each segment, the average ob-submit delay and the update gap distribution, and whether the segment is one targeted for citizen reporting (Table B-5). Ob-submit delay is included to evaluate whether particularly long reporting segments are causing large delays in reporting, and can be calculated using the program in analysis (b). An example analysis (d) is displayed in Appendix B.

Table B-5. Temporal coverage of reports.

Road segment	Targeted segment?	# assigned citizen reporters	Average ob-submit delay	Update gap distribution

Source: Utah DOT

Tracking reporter performance (measure e) will also help UDOT take steps toward improving coverage by getting a sense of what an individual citizen reporter can accomplish in that role. It will help in planning future reporter recruitment. Data to be logged are the frequency of reporting and the usual reporting times of each reporter, as well as their assigned reporting segments (Table B-6). This information can be added to each reporter's profile in the database. Frequency can be expressed as reports per day and can be calculated from the report archive associated with each reporter using a simple program. Usual reporting times can be gathered from the report archive, and do not need to be precise times of day. "Commute times," "overnight," or "varies" are examples which will help UDOT recruit reporters who can report at different times than those currently assigned to specific routes. The information can be sorted by the reporters' assigned segments in order to complete the reporting picture for each route.

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Table B-6. Reporter performance.

Reporter	Assigned segments	Reporting frequency	Usual time of day

Source: Utah DOT

Hypothesis 2: Citizen reporters will provide accurate information to UDOT.

Hypothesis 2 will test the degree to which reporters will provide accurate reports. Following the model for Wyoming's ECAR (Enhanced Citizen-Assisted Reporting) program, all enrolled reporters for UDOT will undergo pre-season training. WYDOT reports that, as a result, report accuracy is satisfactorily high (Vince Garcia, WYDOT ITS Manager, personal communication, 2012). Therefore, all incoming UDOT citizen reports will be assumed accurate, unless the TI Met determines otherwise.

The TI Met, who will actively quality control citizen reports, will review a majority of the incoming information. Inaccuracies will become apparent using nearest neighbor comparison and forecaster expectation, based on road weather data available to them and their experience in interpreting these data. Reports that seem inaccurate will be investigated, and, if found to be erroneous, will be corrected and flagged with a "not helpful" checkbox on the TI Met's internal application. Flagged reports will be tagged to their reporter and archived, and the data will be used for the analysis herein. It is assumed there will be few reports the TI Met has to flag, and that he/she will catch a significant proportion of them. For all reporters, the number of flagged/inaccurate reports and total reports will be summed for grand totals of each, and the fraction of flagged reports per all incoming reports will be calculated. Table B-7 may be used to record this statistic. UDOT has identified 5% as a level of tolerability for inaccurate reports. If inaccurate reports make up less than 5% of the total, Hypothesis 2 is supported.

The TI Mets, who will be flagging the reports, should record the usual nature of the inaccuracies in Table B-7. Possible inaccuracies include: reports entered into incorrect road segments (which may become apparent if a reporter assigned to a given segment makes a report on another), reports contrary to other observations (e.g., report states "clear roads" when cameras, RWIS and/or other citizen reports indicate snow-covered roads), large ob-submit delay and anything else currently unforeseen that may arise during the season. The number of reporters warned or removed can be logged in Table B-7, as well.

Table B-7. Analysis for Hypothesis 2.

Fraction of flagged per all incoming	Nature of inaccuracies:		Reporters warned or removed

Source: Utah DOT

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Hypothesis 3: Internal UDOT operations will benefit from increased road condition reports and forecasts.

The enhanced weather and road conditions information will not only be available to the traveling public, but will also be utilized by internal UDOT personnel. Hypothesis 3 will track the ways in which personnel benefit from the enhanced information, the specifics of which are listed in Table B-1 under the MOEs for Hypothesis 3. Expected outcomes include: (a) UDOT's weather forecasters will use the road condition information to improve upon forecasting capabilities, (b) traffic operators will use road condition reports and forecasts to give motorists better information, (c) TMD managers will use the information to support management of storm events and conduct post-analyses and (d) managers in other divisions in UDOT will use the information to track or improve performance. For example, Maintenance Division managers may want to use road condition logs in performance measurement for their crews, or Traffic and Safety engineers may use the logs when investigating a weather-related incident.

The analysis for the first three listed outcomes of Hypothesis 3 consists of conducting an internal survey of opinions from traffic operators, forecasters and managers located in the TMD. An example survey is shown in Appendix C. Simple data tables can be created to help visualize numbers 1-5 in the survey, and these are also shown in Appendix C. There should be about 20 survey responses. Each survey should be reviewed separately, with the respondent's feedback being weighed by answers to Q1 and Q2: length of time respondent has worked for UDOT and respondent's job title. Survey results will be especially valuable if respondents give detailed examples of ways in which the information helped them perform their job duties. Responding forecasters should be encouraged to give concrete examples of how their ability to produce and verify forecasts was improved. If respondents report not using the enhanced information or that the information was not helpful, follow-up should be done to understand why, and this should be noted. The information gathered here can help guide future development of the program.

For Outcome (d), managers in other divisions in UDOT should be made aware of the enhancement to road condition data before the winter season begins, and they should be encouraged to use the information (realtime or archived) as needed. During project evaluation in spring 2013, these managers should be contacted again and asked whether or how they were able to use the information to better manage their operations. Their responses should be noted along with the survey responses.

Hypothesis 4: The traveling public will make more informed decisions based on the enhanced information.

One of the goals of providing enhanced forecast and road condition information to the traveling public is to give motorists the information they need to make informed travel decisions. These decisions may include: completing travel before a storm, delaying or canceling a trip, changing route or mode of travel, preparing for winter conditions (e.g., packing chains or a winter survival kit), etc. It is expected that with better road weather information, the analyses herein will show that motorists are, in fact, making these travel decisions. Two measures can be used to test the hypothesis (from Table B-1, Hypothesis 4): (a) changes in traffic volume data before, during and after high-impact storms and (b) subjective traveler feedback on decisions-making before and during storms.

UDOT expects traffic volume to increase before or after high-impact storm events (measure a), because travelers will know a more specific starting and ending time to the most impactful portion of a storm, and they will choose to travel around those times, if possible. Data from highly publicized, high impact storm events from previous winters in Utah showed this sort of around-storm shift in traffic. A couple of examples are shown in Appendix D. To do the analysis for measure (a), a few high-impact storm events from 2012/13 should be chosen. Traffic volume or vehicle miles traveled (VMT) can be

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plotted over the hours before, during and after and event. The storm day's data can be compared to average data for that date or to data from the previous week or year, if that time period is comparable to the storm day in question and had no weather impacts. This analysis works best for events that lasted a portion of a day or began during the afternoon. If an event occurs over a highly traveled weekend, e.g., a holiday weekend, traffic volumes over the entire weekend can be compared to the same holiday weekend in previous years. Results should show an increase in traffic above normal prior to the event, and potentially an increase above normal after the event, suggesting informed travelers had chosen to travel early or delay their trip. Because traffic is a multivariate system, the results of these analyses should be taken as implicit, not explicit.

To further bolster the analysis for (a), increased UDOT Traffic website and app usage leading up to an event (outcome b) can imply that travelers are seeking the information, and then making the decision to travel before the storm. Therefore, website and app page views will be plotted in 20-minute intervals throughout the day(s) leading up to and through an event. If traffic data from (a) shows an above average increase in travel prior to the event along with an increase in information usage, the argument is strengthened that the public is making informed decisions about travel.

The third analysis for Hypothesis 4 (c) is a more direct method of assessing traveler decision-making before, during and after winter storms, and how decision-making has changed from previous seasons to the 2012/13 season. The analysis will use traveler feedback through a survey or focus group. An example survey is shown in Appendix E (Fig. 1E), and example analyses are also included in Appendix E. The survey should ensure that the respondents have actually used the enhanced UDOT Traffic weather information and should ask respondents about how the enhanced information made them better able to prepare. Also, note that the analysis can cover the entire season or a single storm.

Hypothesis 5: The traveling public will perceive a benefit from the enhanced information.

There are a number of measures UDOT can use to assess the public's *perceived* benefit from the enhanced road weather information. Under Hypothesis 5 in Table B-1, four measures are listed, which largely concern quantifying usage of the information by the public and user satisfaction with the information. Specifically, they are: (a) traveler awareness of and satisfaction with UDOT Traffic weather forecast information, (b) change in positive/negative public comments on UDOT's weather information, (c) change in usage of road weather information on UDOT's website, and (d) UDOT Traffic app download trends.

The analysis for (a) utilizes an ancillary study not affiliated with this evaluation, which is occurring during winter season 2012/13. The study will, in part, seek to understand traveler awareness of and satisfaction with UDOT and other sources of weather forecast information. It is co-sponsored by the National Weather Service, University of Utah Department of Psychology and UDOT, and is focused specifically on Wasatch Front drivers. After each of three high-impact storms to hit the Wasatch Front during the winter season, surveys will be conducted, asking travelers how they got information about the storm, whether it caused them to alter their travel plans, and if they were satisfied with the information they received. The finalized survey is shown in Appendix F. For the purpose of Hypothesis 5 analysis, UDOT will learn from the study an approximate percentage of Wasatch Front drivers using UDOT Traffic information, and the percentage of users that are satisfied with UDOT's information. Using the results, we can compare user satisfaction with, for example, local media's weather information, versus user satisfaction with UDOT's information. Results should be weighed by the degree to which local media are using UDOT Traffic information in their broadcasts. The study will conclude in spring 2013, and results should be available shortly thereafter.

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Traveler information users have had the ability to leave feedback, whether positive or negative, via email, phone or app rating systems since the technologies were first made available to them. Thus, we can track the change in the proportion of positive or negative weather-related feedback, from previous seasons (as available) to the 2012/13 season. Data from each season should be restricted to December 1 through March 31, in part because the app was not available until December 2011 and the current program won't launch until December 2012. Utilizing 511, email and app feedback logs, the total number of comments (weather-related or not) received over the 4-month time period of each season should be recorded in the "all feedback" column of Table B-6. The "All" row can be used as a sum of the three categories (web, app, 511). If a comment in any way references weather or road conditions, it should be counted as being "weather-related." UDOT staff will subjectively decide whether a comment is positive or negative, based on its overall content. The weather-related positive and negative comments will be tallied and entered into Table B-8. The tallies should be converted to percentages of "all feedback" and recorded, as well. Table B-9 can be used to summarize Table B-8 and produce line graphs, if needed, for visualization. If the trend of positive (negative) feedback increases (decreases) from prior seasons to 2012/13, then analysis (b) has contributed toward supporting Hypothesis 5. It could also be helpful to record a few of the user comments which can be used to shape the program in future seasons. Additionally, it may be interesting to note whether the proportion of all weather-related comments (positive or negative) increased during 2012/13. This might suggest an increased focus of the public on road weather, and the desire to help UDOT provide quality information.

Table B-8. Traveler information user feedback statistics.

| | Dec-Mar 201X/1X | | | Dec-Mar 2012/13 | | |
| | All feedback | Weather-related feedback | | All feedback | Weather-related feedback | |
	Total	Positive	Negative	Total	Positive	Negative
Web		%	%		%	%
App		%	%		%	%
511		%	%		%	%
All		%	%		%	%

Source: Utah DOT

Table B-9. Summary sheet for Table B-8.

Positive

	Web	App	511	All
2010/11	%	%	%	%
2011/12	%	%	%	%
2012/13	%	%	%	%

Negative

	Web	App	511	All
2010/11	%	%	%	%
2011/12	%	%	%	%
2012/13	%	%	%	%

Source: Utah DOT

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The analyses for measures (c) and (d) will track public usage of road weather information on the UDOT Traffic website and app, respectively. If user statistics during 2012/13 increase, then we may assume the traveling public wants to seek out UDOT's weather information and finds the information beneficial, especially if the analysis for (b) above shows growing satisfaction with the information. There are a few important notes for the usage analyses:

1. Only 2011/12 and 2012/13 will be comparable, since the current structure of the UDOT Traffic website and the app were not introduced until 2011.

2. As in analysis (b), a season will be defined as Dec 1 – Mar 31.

3. The storminess of a season will have a significant impact on how often the public accesses weather information. In order to mitigate the influence of storminess on season-to-season or month-to-month usage variability, the data should be normalized by the number of storm days per season or month. A day is counted as a "storm day" if a winter storm is impacting conditions on any Utah state roadway. Storm days can be summed from storm report folders and noted in Table 10. Usage will be divided by storm days, and the resulting units will be users/storm day.

4. Although not every storm day has the same impact on Utah's roadways, we will assume that over the course of each season, storm impacts average out, reducing the need to consider impact in the analysis herein.

Table B-10. Storm days per season.

# storm days				
Dec	Jan	Feb	Mar	Total
2011/12				
2012/13				

Source: Utah DOT

The two pages of interest on the UDOT Traffic website are the road weather page (RWP, udottraffic.utah.gov/RoadWeatherForecast.aspx) and the Road Weather Alert (RWA, udottraffic.utah.gov/SLAlertViewer.aspx?CLType=2). For each page, user page views will be tallied for each month, then summed over the whole season, and divided by the number of total storm days. These statistics can be entered into Table B-11, and monthly statistics (monthly tallies divided by monthly storm days) can be entered into Table B-12. These month-to-month statistics will provide greater data points and will help to identify trends throughout each season. Trend line plots can be created for the monthly data, and average increase in page access per month can be calculated. See Appendix G for a detailed analysis of example statistics.

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Table B-11. Total webpage view counts per storm day for each season (Dec 1 – Mar 31)

	Page views/storm day	
	2011/12	**2012/13**
RWP		
RWA		

Source: Utah DOT

Table B-12. Total webpage view counts per storm day for each month.

	Page access/ storm day	
	RWP	**RWA**
Dec-11		
Jan-12		
Feb-12		
Mar-12		
Dec-12		
Jan-13		
Feb-13		
Mar-13		

Source: Utah DOT

Similar to websites, we can log usage for apps, but we can also track the number of downloads. Again, usage, but not downloads, will be normalized by storm days (Table B-10). An important aspect of the usage statistics for the UDOT Traffic app is that they do not distinguish between the types of information users are accessing. Nevertheless, UDOT can track these page views to approximately track app usage. Downloads are not a direct proxy for usage, but they do imply an interest in the information offered. App ratings should be noted, as well. Table B-13 can be used to record the number of downloads and page views/storm day per platform and per season, and Table B-14 for monthly analysis. Download values should be cumulative; that is, the total number of downloads to date. The example scenario in Appendix G can also be applied to app usage statistics.

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Table B-13. Cumulative app downloads and total page view counts per storm day for each season (Dec 1 – Mar 31)

	Downloads		Page views/ storm day	
	2011/12	2012/13	2011/12	2012/13
Android				
iPhone				
iPad				
All				

Source: Utah DOT

Table B-14. Cumulative app downloads and total page view counts by month.

	Downloads	Page views/ storm day
Dec-11		
Jan-12		
Feb-12		
Mar-12		
Dec-12		
Jan-13		
Feb-13		
Mar-13		

Source: Utah DOT

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Challenges and Constraints

Table B-15 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-15. Potential project challenges and constraints and strategies used to mitigate them.

Challenge/Constraint	Mitigation Strategy
The ideal amount of citizen reporters per route segment is 8-10; however, that number may not be reached the first season.	Hypothesis 1 will measure the quantity of citizen reports actually being received. Where citizen reporters don't fulfill the goal of an updated condition report every two hours, TI Mets will supplement by reporting from the office.
The impact on the transportation system of a traveler information strategy is difficult to measure explicitly.	Implicit analyses are used in Hypotheses 4 and 5 to suggest that the program is having a positive impact on individual travelers and system-wide traffic.
Conducting a user survey, as in Hypothesis 4, may not be possible during spring 2013 due to resource and timing constraints.	There are a number of options: (1) If possible, the TMD could piggyback off of survey or focus group projects led by UDOT Public Information. (2) If not possible during spring 2013, the survey may be delayed, but it would not be included in this analysis. (3) A digital survey can be built into website and/or app, but would be needed by April.
Variability in storminess from month to month or season to season can skew traffic and traveler information data, such as TI usage statistics in Hypothesis 5.	Data can easily be normalized by the number of storm days – one indicator of storminess – but less easily by the severity of the storms that occur. We assume herein that severity averages to moderate (rather than low or high) impact over the course of each season.
App usage data is unavailable for current and previous seasons.	App downloads may be used as a proxy for usage – though an imprecise one – if we assume that the majority of users who have downloaded the app are using it with some regularity.
Season-to-season comparison is difficult due to a lack of data in previous seasons.	Data is often available from at least 2011/12, though that still only leaves one season against which 2012/13 can be compared. A higher granularity of analysis (e.g., monthly) is better for trend analyses.
There are few or no quantitative performance metrics to use to evaluate the impact of road condition and forecast information on personnel job performance (Hypothesis 3).	Qualitative or anecdotal evidence can provide perceptions of job performance, as well as suggestions and feedback that can be used to improve internal usage of the weather information.

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Challenge/Constraint	Mitigation Strategy
Utah will get too few storms during the 2012/13 season to yield adequate data for the evaluation.	Hypotheses 1 and 2 are not dependent on storms, as citizen reporters will report even when the weather is dry. For Hypotheses 3, 4 and 5, climatologically, there will be at least a few impactful storms that will require UDOT personnel and the public to utilize road weather forecasts and condition reports. Even with a small number of events, the public will have a chance to use the enhanced information. Moreover, the evaluations can be performed again in subsequent years to increase data sample sizes.

Source: Utah DOT

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Exhibit A – National Weather Service Radar Coverage
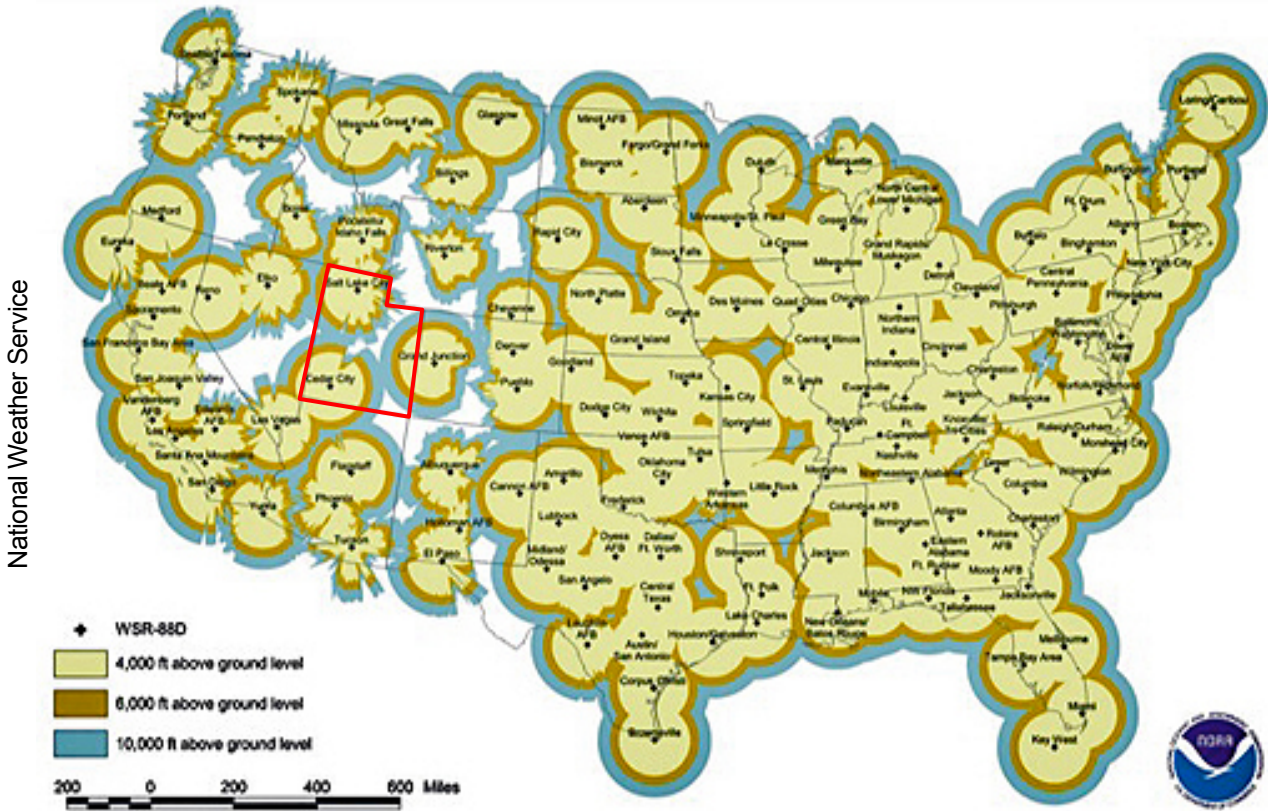
Figure 1A. Map of National Weather Service radar coverage throughout the country, with Utah outlined in red. Black dots indicate radar sites. Because the radar beam leaves each site at a 5-degree angle upward the yellow, brown and blue bands on the map indicate the distance of the beam at which its height is less than 4,000, 6,000 and 10,000 ft above ground level (AGL), respectively. Most winter precipitation in Utah, however, falls from around 5,000-7,000 ft AGL (10,000-12,000 ft above sea level), and therefore the blue band (6,000-10,000 ft AGL) represents a portion of the radar beam that overshoots many winter storms. The effective radar coverage in the wintertime in Utah is actually what is shown in yellow and brown. What's more, mountain peaks block the radar beam through the central part of the state. The combination of overshooting radar beams and terrain blocking leaves large gaps in Utah without radar coverage. (Image courtesy National Oceanographic and Atmospheric Association)

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Table 1A. Citizen reporting routes which target critical gaps in weather and road condition observation.

Segment #	Segment Name	UDOT Region
1	I-15 Idaho Stateline to Tremonton	Region 1
3	I-15 Tremonton to Jct SR-240 at Honeyville	Region 1
5	I-15 Honeyville to Box Elder/Weber Co Ln	Region 1
21	I-15 Spanish Fork to Payson	Region 3
23	I-15 Payson to Juab Co Ln	Region 3
25	I-15 Juab Co Through Nephi	Region 3
27	I-15 Juab/Millard Co Ln to Holden	Region 4
29	I-15 Holden through Meadow	Region 4
31	I-15 Exit 144 through Cove Fort	Region 4
33	I-15 Exit 120 through Beaver to Exit 95	Region 4
35	I-15 Through Parowan	Region 4
37	I-15 Through Cedar City	Region 4
45	I-70 Clear Ck Summit through Richfield	Region 4
47	I-70 Through Salina to Fremont Jct	Region 4
49	I-70 Fremont Jct to Ghost Rocks	Region 4
51	I-70 Ghost Rocks to Crescent Jct	Region 4
53	I-70 Crescent Jct to Colorado Stateline	Region 4
69	I-80 US 40 Jct at Silver Ck to Wanship	Region 2
71	I-80 Wanship to Echo Jct	Region 2
80	I-84 SR-167 at Mountain Green to Morgan	Region 1
81	I-84 Uintah Jct to Jct SR-167 at Mountain Green	Region 1
82	I-84 Morgan to Henefer	Region 1
83	I-84 Henefer to I-80 at Echo Jct	Region 2
95	US 6 Colton to Helper	Region 4
97	US 6 Helper through Price	Region 4
101	SR-31 Huntington Canyon	Region 4
107	US-89 Lower Logan Canyon	Region 1
111	US-89/91 Wellsville to Logan	Region 1
113	SR-150 Kamas to Mirror Lake Gate	Region 2
141	SR-16 Through Randolph and Woodruff	Region 1
151	SR-30 Garden City to Wyoming Stateline	Region 1
153	SR-35 Francis to Woodland	Region 2

Segment #	Segment Name	UDOT Region
169	US-40 Through Daniels Canyon	Region 3
170	SR-44 Greendale Jct to Manila	Region 3
171	SR-73 Lehi to Fairfield	Region 3
181	SR-92 American Fork Canyon	Region 3
182	US-191 Vernal to Greendale Jct	Region 3
183	US-191 Duchesne to Helper through Indian Canyon	Region 3
184	US-191 Greendale Jct to Wyoming Stateline	Region 3
195	SR-9 Through Zion National Park	Region 4
199	SR-10 Huntington to Ferron	Region 4
201	SR-10 Ferron to Fremont Jct	Region 4
206	SR-24 Richfield to Loa	Region 4
210	SR-28 Nephi South	Region 3
211	SR-28 Gunnison North	Region 4
213	US-50 Delta to Holden	Region 4
217	SR-56 Cedar City to the Nevada Stateline	Region 4
219	US-89 Thistle South to Sanpete Co Ln	Region 3
220	US-89 Through Mt. Pleasant	Region 4
221	US-89 Manti to Salina	Region 4
222	US-89 Sevier to Circleville	Region 4
223	US-89 Circleville to Panguitch	Region 4
225	US-89 Panguitch to Kanab	Region 4
229	SR-95 Lake Powell to Blanding	Region 4
231	SR-128 Moab to Cisco	Region 4
237	US-6/191 Price to Green River	Region 4
239	US-191 Cresent Jct to Moab	Region 4
241	US-191 Moab to La Sal Jct	Region 4
243	US-191 La Sal Jct to Monticello	Region 4
245	US-191 Monticello to Blanding	Region 4
246	US-191 Blanding to Bluff	Region 4
247	US-191 Bluff to Arizona Stateline	Region 4

Source: Utah DOT

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Exhibit B – Example evaluation scenario

The following is an example scenario (on following page) using targeted segments and analysis from Hypothesis 1 to show how the evaluation can be used to prioritize targeted observation gaps.

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Segment	Targeted segment?	# citizen reporters	Ob-submit delay
I-70 Clear Creek Summit thru Richfield	YES	10	5 min
SR-24 Richfield to Loa	YES	2	45 min
I-15 Roy to Farmington	NO	0	5 min

Road Segment: I-70 Clear Creek – Richfield		
Update Gap Category	Tally	Proportion
≤ 2 hours	300	43%
> 2 and ≤ 4 hours	210	30%
> 4 and ≤ 6 hours	100	14%
> 6 and ≤ 12 hours	55	8%
> 12 and ≤ 24 hours	30	4%
> 24 hours	5	1%
Sum of tallies	700	
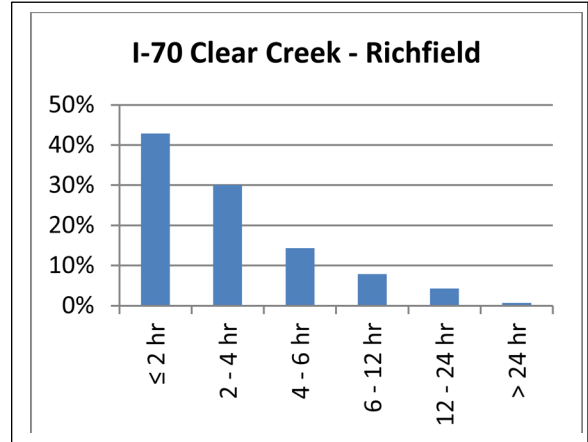
Road Segment: SR-24 Richfield to Loa		
Update Gap Category	Tally	Proportion
≤ 2 hours	10	4%
> 2 and ≤ 4 hours	10	4%
> 4 and ≤ 6 hours	30	12%
> 6 and ≤ 12 hours	80	32%
> 12 and ≤ 24 hours	100	40%
> 24 hours	20	8%
Sum of tallies	250	
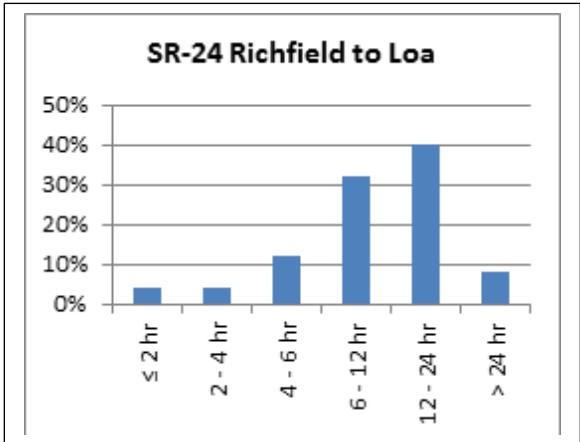
Road Segment: I-15 Roy to Farmington		
Update Gap Category	Tally	Proportion
≤ 2 hours	2	1%
> 2 and ≤ 4 hours	3	2%
> 4 and ≤ 6 hours	5	4%
> 6 and ≤ 12 hours	15	11%
> 12 and ≤ 24 hours	10	7%
> 24 hours	100	74%
Sum of tallies	135	

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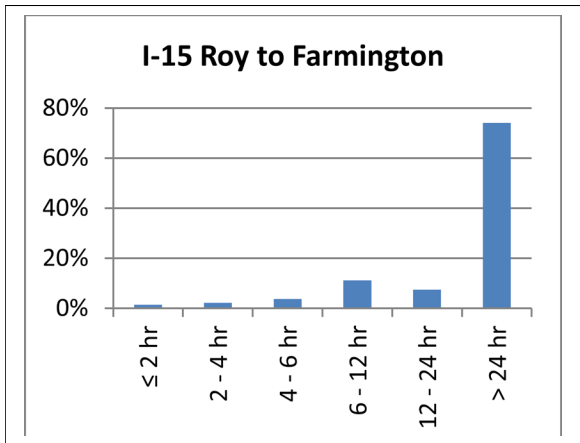
Shown above are plots of update time gap for 3 road segments, two of which are targeted in Hypothesis 1 for citizen reporting priority. These are example scenarios. Note that I-70 Clear Creek to Richfield has 73% of its reports occurring within 4 hours of each other, and 40% occurring within 2 hours of each other. This is likely because, as an interstate segment, it has a large number of citizen reporters traveling at all times through the day. For the SR-24 Richfield to Loa junctions with the I-70 segment, however, a much larger fraction of its reports occur between 6 and 24 hours of each other, leaving large gaps in time without road condition updates. It is a 2-lane highway to a small town, but needs more citizen reporters along it. Also, the average ob-submit delay for SR-24 is large, and may necessitate providing different reporting options for reporters on that route. I-15 Roy to Farmington has no assigned citizen reporters, and therefore frequently has gaps in update times of more than 1 day. This segment however was not targeted for citizen reporting, as it has a number of live traffic cameras and RWIS stations along it, and is therefore well observed by other means. As a result, the relatively poor update time gap statistics for I-15 do not necessitate action; however, UDOT may choose to recruit more citizen reporters for highways like SR-24, where observations are scarce. Furthermore, UDOT can evaluate the performance of the citizen reporters (measure e, Hypothesis 1) on SR-24 to help guide recruitment for additional reporters along that route.

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Exhibit C – Example Survey for use in Hypothesis 4.

This winter season (2012/13), UDOT instituted a citizen reporting program for TATS updates and enhanced weather forecasting. We want to understand if this program helped to improve your situational awareness and your ability to do tasks related to your job.

1. How long have you worked for UDOT? _____
    Prior to this winter, which winter seasons have you worked (circle all that apply):

            Before 2009   2009/2010   2010/2011   2011/2012

2. What is your job position? (Circle one.)

                                Maintenance Weather   TMD
            Traffic Operator   Forecaster   TI Meteorologist   Manager

3. During winter 2012/13, how often did you refer to UDOT Traffic for road conditions (TATS) or weather forecasts? (Circle one.)

                Very rarely   Rarely   Occasionally   Frequently   Very frequently

    Did you look at this information *only* during storms? (Circle one.)   YES   NO

4. During winter 2012/13, I used TATS and/or the road conditions as support in doing one of the following: (Mark all that apply.)

    ___ Posting a VMS   ___ Helping a public motorist on the phone   ___ Making a forecast

    ___ Making a management-level decision   ___ Verifying a forecast

    ___ Performing an after-action review   ___ Other:_____

5. Please indicate your agreement with the following statements:

    During winter season 2012/13, the updated TATS information and road weather forecasts on UDOT Traffic helped me to do my job better. (Circle one.)

            Strongly   Neither agree nor   Strongly
            disagree   Disagree   disagree   Agree   agree

    If winter 2012/13 was *not* your first season working for UDOT, do you feel that the UDOT Traffic TATS and weather information during 2012/13 helped you to do your job *better* than in previous seasons? (Circle one.)

Figure 1C. Example survey for use in Hypothesis 4.

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Q1.	See example statistics below.
	By specifying which winter seasons personnel have worked, we can weigh their responses based on the sort of weather information they had used in the past.
Q2.	By indicating job position, responses to the rest of the questions will be clearer. Responses to Q2 can also be displayed for a quick view of respondent type, as in the example below.
Q3.	See example statistics below.
Q4.	This question gets respondents thinking about how the information specifically helped them do their job, and gives them the chance to suggest another.
Q5.	See example statistics below.
	Because there will be less respondents for the YES/NO question, it is helpful to note that.
Q6.	Open format. If possible, encourage respondents to come up with as many varied examples as they can. It may also be helpful to tell them at the beginning of the season that they are going to be asked to recall these experiences in the spring.

Q1. Length of time respondents have worked for UDOT.
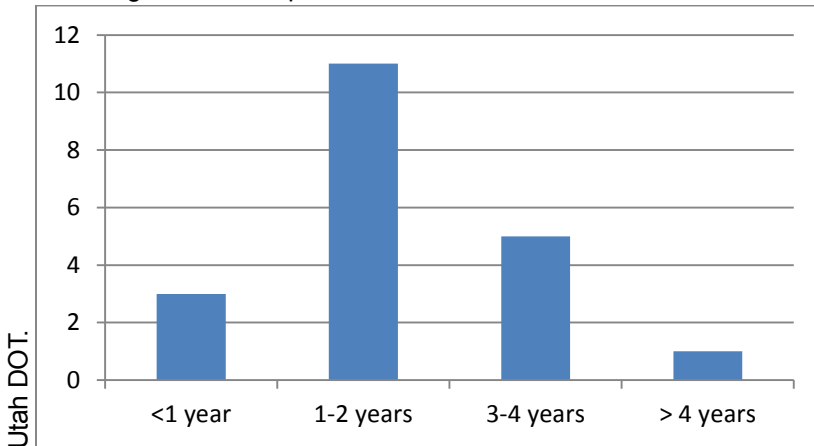
Q2. Job position of respondents.

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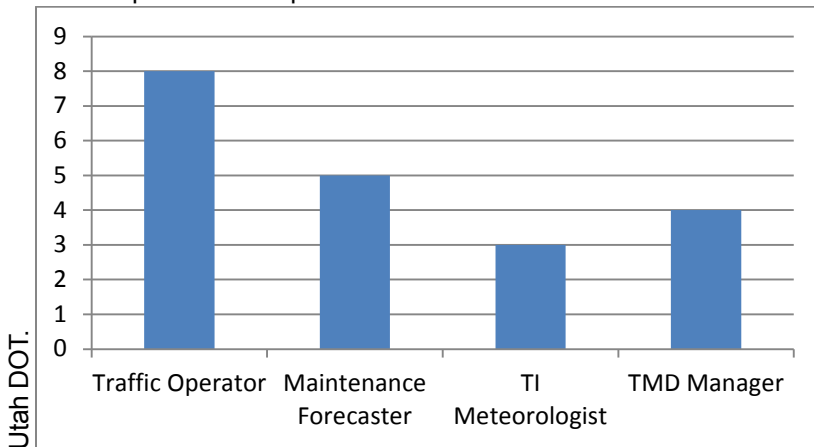
Q3. Frequency that respondents referred to UDOT Traffic for road conditions or weather forecasts.
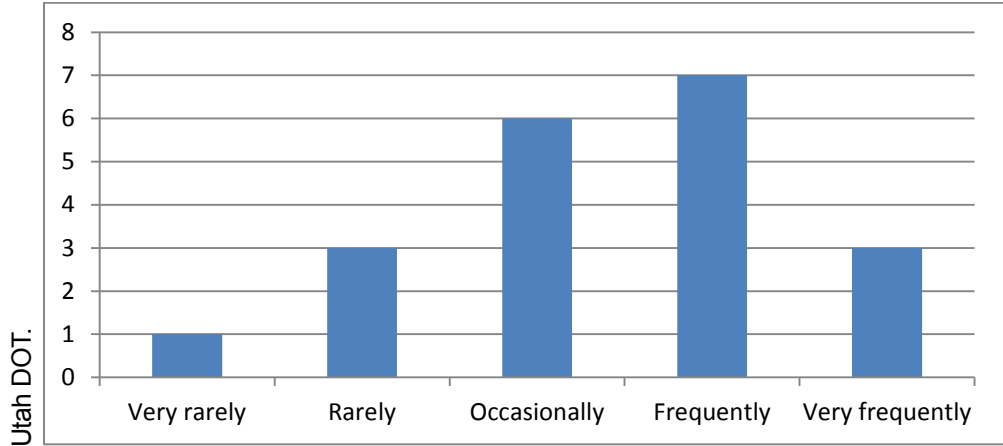
Did you look only during storms?	
YES	5
NO	15

Q5. "During winter season 2012/13, the updated TATS information and road weather forecasts on UDOT Traffic helped me to do my job better."
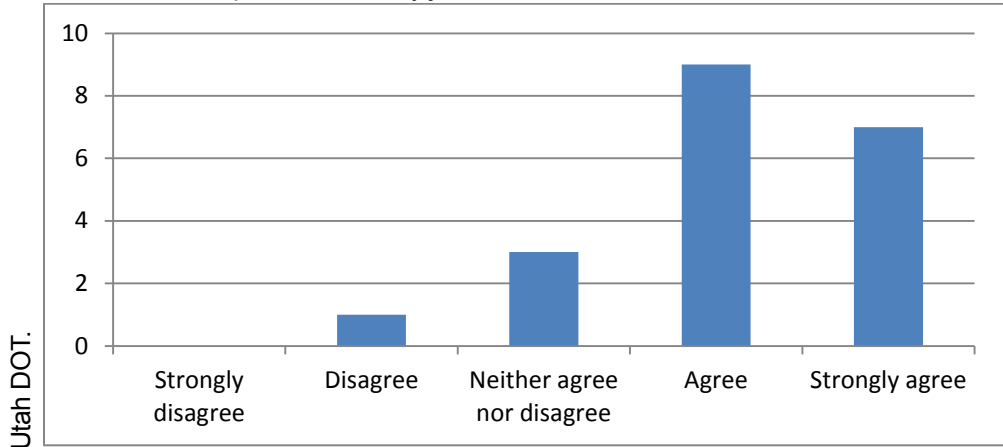
Did the information help you do your job better in 2012/13 than in previous seasons? (17 respondents)	YES	14
	NO	3

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Exhibit D – UDOT Snow Plow Plots

Snow Event (12/19/08)
I-15 SB 8600 S

- Mean Flow
- Event Flow
- Event Speed * 100

Snow Event (1/5/09)
I-15 SB 8600 S

- Mean Flow
- Event Flow
- Event Speed * 100

Time of Day

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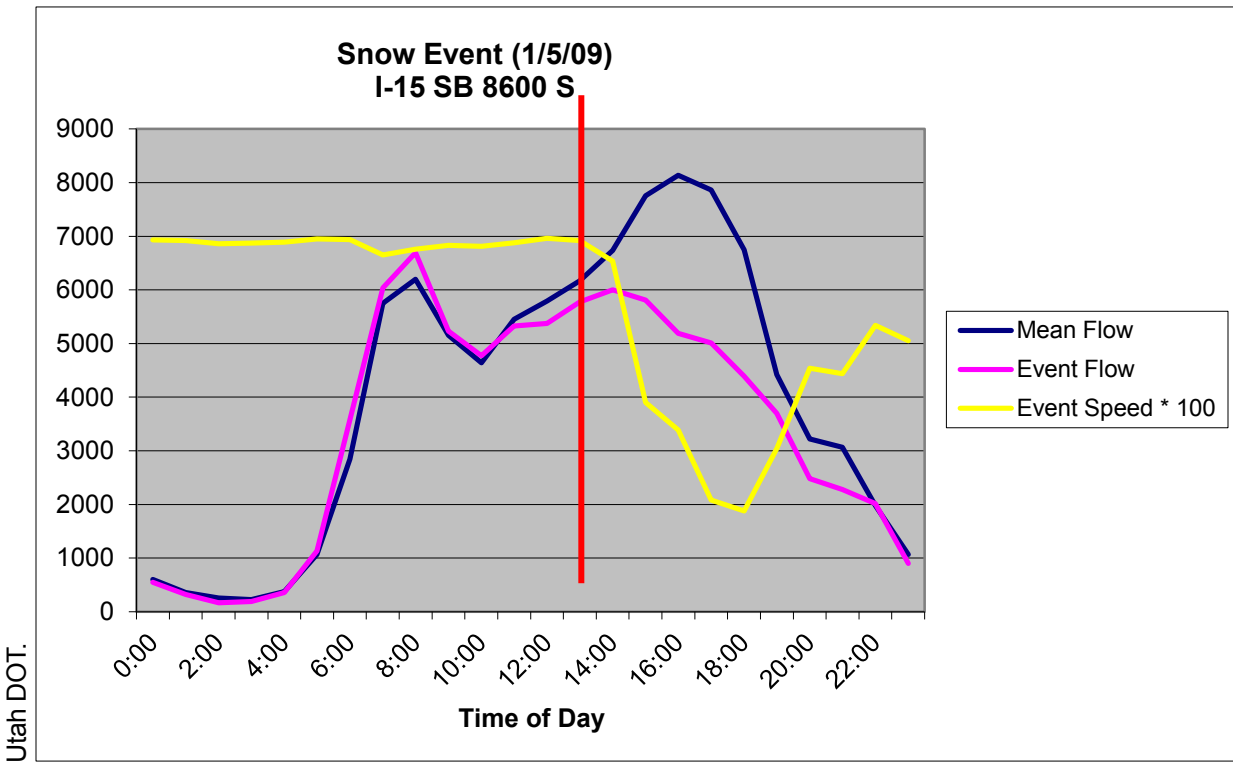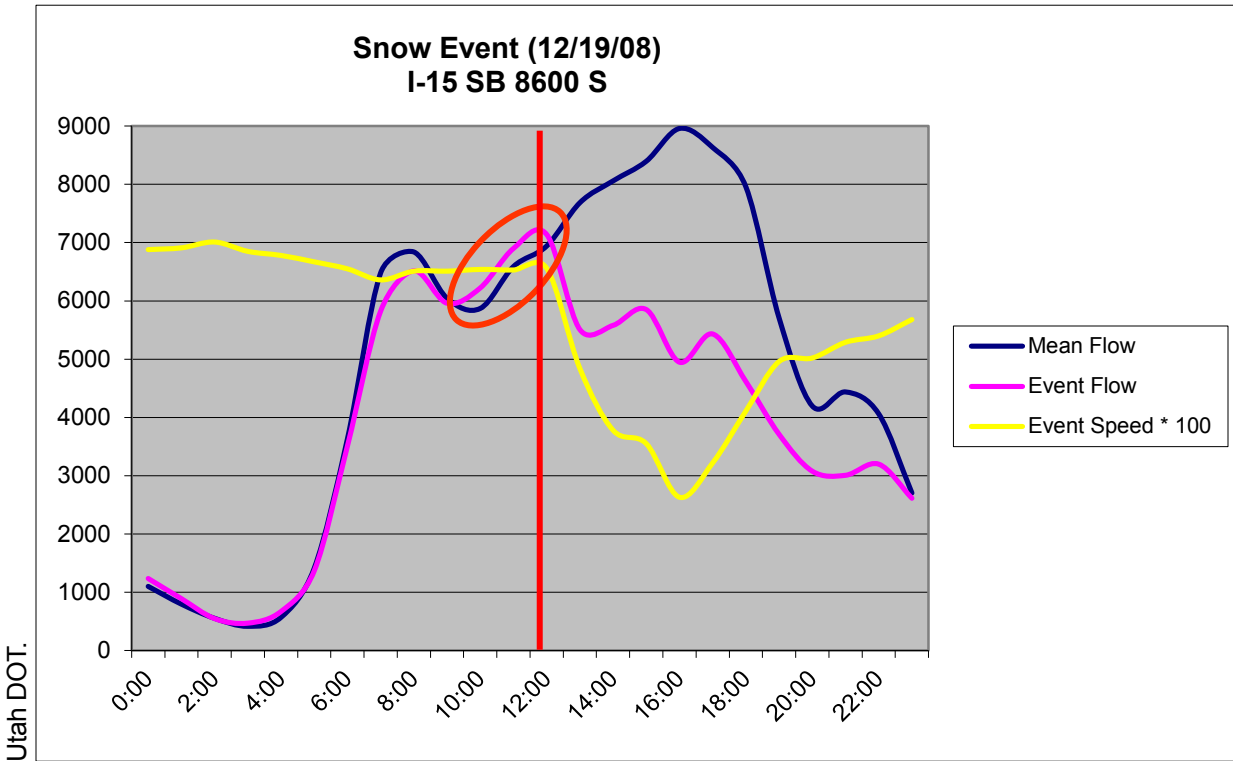
Figure 1D (previous page). Plots from two snow storm days, 19 Dec 2008 and 5 Jan 2009, showing mean (historic) traffic flow and daily flow and speed, on I-15 SB at 8600 S (from Glen Merrill, et al., NWS Salt Lake City, 2009). The vertical red line denotes the start of the snow event. Note that there is an increase in traffic flow just before the storm on Dec 19th (circled in red), that is not present on Jan 5th. Although there could be a number of contributors to the difference in pre-event traffic flow between the two days, one possible explanation is that travelers heeded road weather forecasts for Dec 19th and chose to complete their discretionary travel before the storm hit. At the time of these events, road weather forecasting for public use was in its infancy in Utah. The National Weather Service office in Salt Lake City and the UDOT Traffic Management Division worked with local media to alert the public to the Dec 19th storm's impacts. The same effort was not put forward on Jan 5th.
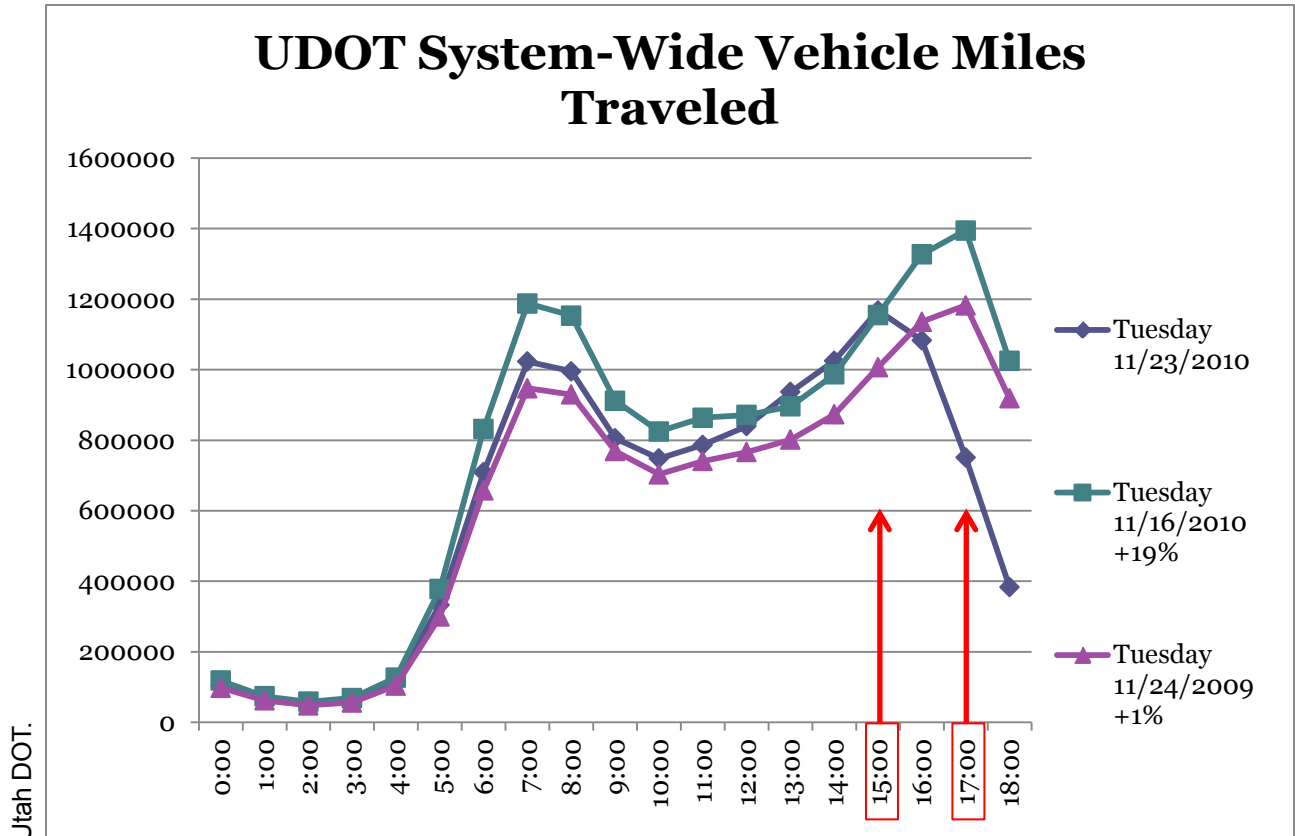
Figure 2D. Plot showing system-wide vehicle miles traveled (VMT) for three days, each a Tuesday: 24 Nov 2009, 16 Nov 2010 and 23 Nov 2010 (Brad Lucas, UDOT TMD, 2010).

This example compares two days without snow (11/24/09 and 11/16/10) to one with a snow event that began at 5 pm (11/23/10). The event was highly publicized, as it was anticipated to be high-impact. Note that total VMT was decreased on 11/23/10 compared to the week before, in part because the 23rd was 2 days before Thanksgiving. Note also that, despite the overall decrease in VMT, there was a strong increase around 3 pm, when the afternoon traffic peak occurred early. Many businesses and government agencies let their employees leave work around 3:00. Traffic signals had to be switched into peak volume timing early. It is likely that the early afternoon peak was due to the wealth of weather information prior to the event.

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Exhibit E – Sample Survey for use in Hypothesis 4

We want to understand how travelers used UDOT's road weather forecasts and road condition information during the <u>winter season of 2012/13</u>*.

1. During <u>winter season 2012/13</u>*, did you view the road weather forecasts and road condition information available on the UDOT Traffic website, smartphone app or 511? (yes or no) _____
   a. (If *yes*, go on to question #2.)
   b. (If *no*, ask the following question, and then end the survey.) What are your sources for road weather information? _____

2. Did you notice that the road weather forecasts and road condition information on the UDOT Traffic website, smartphone app and/or 511 phone line had improved for the 2012/13 winter season, compared to previous seasons? (yes or no) _____

3. (If *yes* to prior) During <u>the past winter season</u>*, did you use the information to prepare in one of the following ways? (choose all that apply)

   ___ Traveled early or delayed travel

   ___ Canceled trip

   ___ Changed route

   ___ Changed mode of transport (e.g., took bus or Trax rather than drove)

   ___ Prepared to encounter winter conditions (e.g., packed chains or winter survival kit)

   ___ Other: _____

   ___ I did not use the information to prepare for travel before or during a winter storm. (If this option is selected, end the survey.)

4. Indicate your agreement with the following statement:

   During <u>winter season 2012/13</u>*, I was better able to prepare for travel before or during winter storms using UDOT Traffic information compared to previous winter seasons.

   ___ Strongly disagree

   ___ Somewhat disagree

   ___ Neither agree nor disagree

   ___ Somewhat agree

   ___ Strongly agree

*Can replace with "<u>the most recent winter storm.</u>"

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Figure 1E. Example survey for use in Hypothesis 4.

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Q1.	If *no*, and the sources of information are local media, follow up with the stations. Have they been using UDOT weather information?
Q2.	This question will isolate the respondents to those who are able to compare this season's information with previous season's information.
Q3.	See example statistics below.
Q4.	See example statistics below.

Q3

Total respondents	300	
Traveled early or delayed travel	240	80%
Canceled trip	30	10%
Changed route	200	67%
Changed mode of travel	100	33%
Prepared to encounter hazardous conditions	275	92%
Other	10	3%

Survey respondents who used enhanced information to prepare for winter storms

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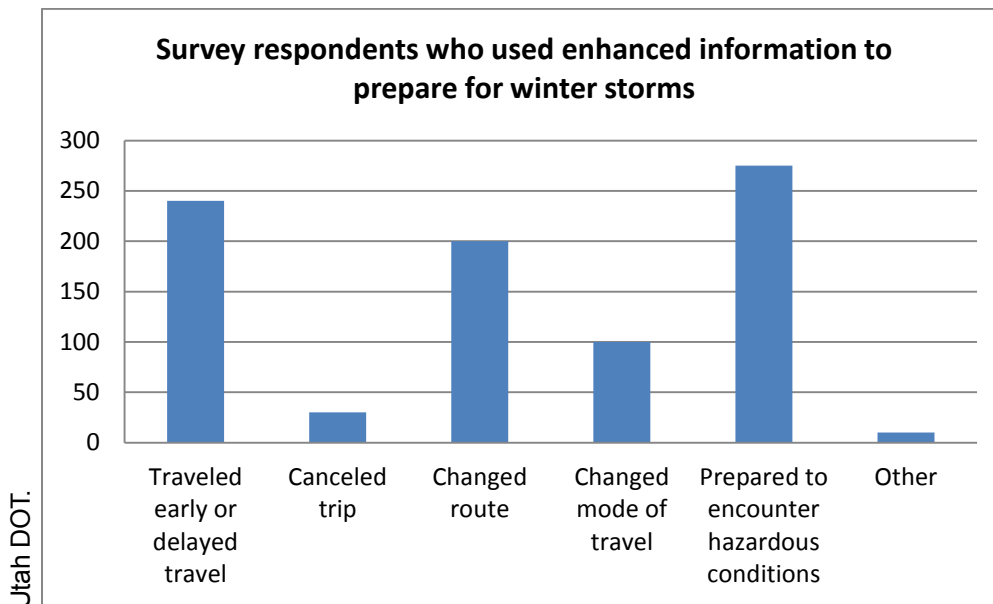
Q4

Total respondents	300	
Strongly disagree	5	2%
Somewhat disagree	10	3%
Neither agree nor disagree	80	27%
Somewhat agree	180	60%
Strongly agree	25	8%

Responses to the statement: "During winter season 2012/13, I was better able to prepare for travel before or during winter storms using UDOT Traffic information compared to previous seasons."

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Exhibit F – Survey of Driver Awareness of and Response to Significant Weather Events in Salt Lake City, Utah during the Winter of 2012-2013.

Survey is provided on following pages.

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Title: Driver's Awareness of and Response to Significant Weather Events
and the Correlation of Weather to Road Impacts

I'm calling on behalf of the University of Utah, the Utah Department of Transportation, and NOAA's National Weather Service.   I'd like to ask you a few questions, but first I need to make sure you are somewhere safe to talk on the telephone. Are you driving right now?

  If "No," continue below (A).
  If "Yes": Sorry, I cannot interview you while you are driving. We'll call you at another time. Thank you.
  Good Bye.

Before we begin, I need to make sure you are eligible to participate.
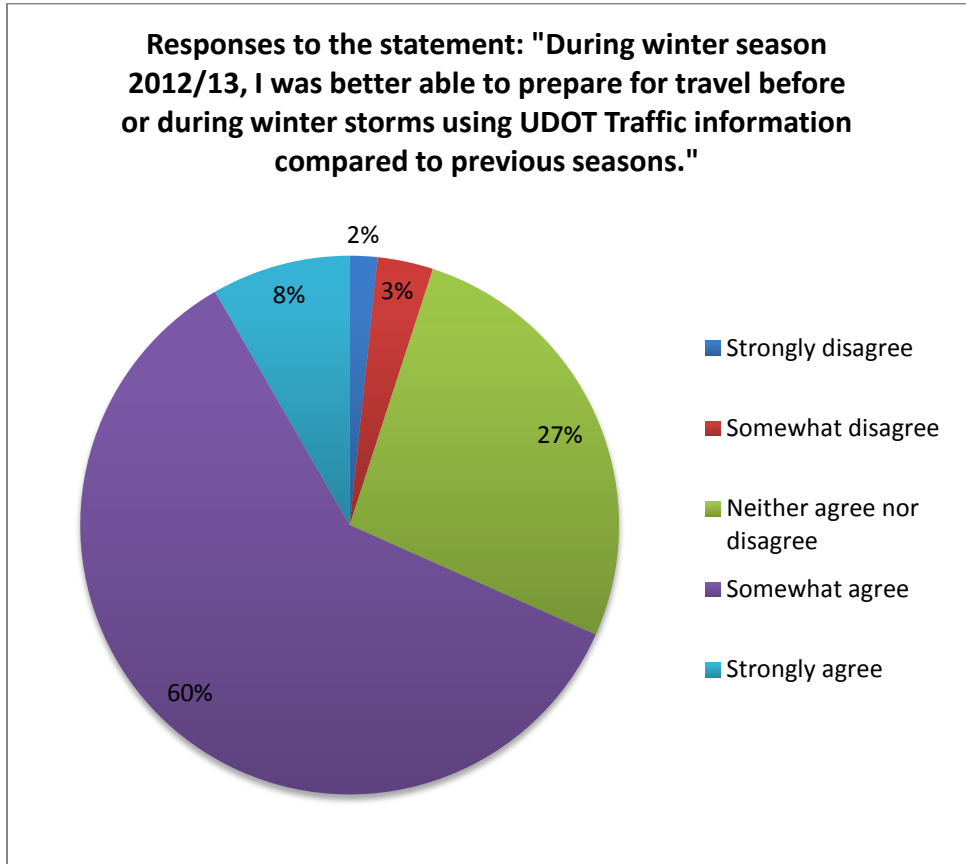
Are you 18 or over   No   Yes

Do you have a driver's license for driving in Utah? No   Yes

Do you live in one of these areas: South Davis, Salt Lake County or Summit County?   No   Yes

Do you travel regularly in the Salt Lake Valley?   No   Yes

  If "No" to any of these, end the interview at that question: " I'm sorry you are not eligible, thank you
  for your time."

  If "Yes" to all four continue: " You are eligible to participate. Let me briefly explain our survey."

I would like to ask you 10 to 15 questions which will take 5 to 10 minutes. Your participation is voluntary, and you are free to skip any questions you choose not to answer.

Your answers are completely confidential. We are not recording your name or telephone number; we use only code numbers in our data file. This interview might be audio-recorded for quality control and to check your answers to open-ended questions. The tapes will be destroyed once we are certain we have accurately typed up your responses.

You can call the researcher, Carol Werner at (801) 581 8938 or you can contact the University's Institutional Review Board (IRB) if you have questions or concerns about your participation or how you were treated. The University of Utah IRB may be reached by phone at (801) 581 3655 or by e-mail at irb@hsc.utah.edu

Are you willing to participate in this survey? We would appreciate your help.

1. In the past few years have you used the bus or TRAX to travel in Salt Lake County?
  No   Yes   Don't remember

2. In the past few years, have you carpooled to travel in Salt Lake County?
  No   Yes   Don't remember

Now I'd like to ask you some questions about your travel yesterday:

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3. Did you travel yesterday in Salt Lake County?

        No   Yes   Don't remember

        If "NO" go to 4, 5 and 6

        If "YES" go to 7, 8 and 9

        If "DON'T REMEMBER" Probe: Take a moment to think about whether you went out yesterday.
                If still don't remember, end interview.

4. Did you NOT travel in Salt Lake because of the storm and driving conditions?   No   Yes

5. Did you NOT travel because your work or school was closed yesterday? No   Yes

6. Did you NOT travel for other reasons (If yes, specify) _____

GO TO 9a

7. Which mode did you use MOST for traveling yesterday? Did you drive alone, carpool, or use transit?

        Drove alone   carpooled   used transit

8. What were your reasons for traveling yesterday?

        8a. Did you commute to or from work or school?   No   Yes

        8b. Did you travel to or from a recreation spot?   No   Yes

        8c. Did you travel to or from health care or other appointments   No   Yes

        8d. Did you travel for other reasons, such as errands, to see friends or entertainment?

            No   Yes

9. Before you traveled, were you aware that a winter storm was coming?

        No   Yes   Don't know/don't remember

        If "No" or Don't know/don't remember," go to 11

        If "YES" go to 10

        9a. Before you decided NOT to travel yesterday, were you aware that a winter storm was coming?

        No   Yes   Don't know/Don't remember

        If "NO" or "Don't know/Don't remember," go to 17

        If "YES" go to 10

10. We'd like to know how people learned about the storm. I'm going to read you a list of sources that provide weather information. Please tell me which sources provided you with information before or during the storm yesterday:

        10a. Could you see it was snowing before you began your trip?

        No   Yes   Don't know/don't remember

        10b. Did you obtain information about the storm from one of the local TV weather reporters – not a national broadcast, but a local TV weather report ?

        No   Yes   Don't know/don't remember

        10c. Did you obtain information about the storm from a nationwide news or weather broadcast?

        No   Yes   Don't know/don't remember

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10d. Did you obtain information about the storm from a local radio station?
No   Yes   Don't know/don't remember

10e. Did you obtain information about the storm on NOAA Weather Radio All Hazards (also called NWR)?

No   Yes   Don't know/don't remember

If Yes, continue here 10e1.
If "no" or "Don't know/Don't remember" go to 10f

10e1. How satisfied were you with the NOAA Weather Radio All Hazards service information?
satisfied
dissatisfied
A mix of satisfied and dissatisfied

10f. Did you obtain information about the storm from a friend, family member or neighbor?
No   Yes   Don't know/don't remember

10g. Did you obtain information about the storm was coming by using social media, such as Facebook or Twitter?
No   Yes   Don't know/don't remember
For any answer, continue with 10i.
10h1. How satisfied were you with the social media site?
satisfied
dissatisfied
A mix of satisfied and dissatisfied

10h. Did you obtain information about the storm by using the UDOT Traffic smartphone app?
No   Yes   Don't know/don't remember
If Yes, continue here 10g1.
If No, to next question 10h
10g1. How satisfied were you with the UDOT Traffic app?
satisfied
dissatisfied
A mix of satisfied and dissatisfied

10i. Did you obtain information about the storm by visiting the UDOT Traffic website?
No   Yes   Don't know/don't remember

If "No," or "Don't know/don't remember" go to 10i2
If Yes continue here 10i1:

10i1. How satisfied were you with the UDOT Traffic information?
satisfied
dissatisfied
A mix of satisfied and dissatisfied

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10j. Did you obtain information about the storm by visiting the National Weather Service website?
No   Yes   Don't know/don't remember

If "No" or "Don't know/don't remember," go to 11
If Yes, continue here 10j1:
> 10j1. How satisfied were you with the National Weather Service website?
> satisfied
> dissatisfied
> A mix of satisfied and dissatisfied

The next questions ask your views about the storm.

11. I understood the possible impacts of the winter storm based on the information that I had
Completely agree
Somewhat agree
Neutral
Somewhat Disagree
Completely Disagree

12. Which of the following best represents your feelings about the storm's severity?
The storm was less severe than I expected
The storm was as severe as I expected
The storm was more severe than I expects

13. Across all your sources of information, how satisfied were you with the information that you received about the winter storm and driving conditions?
Very satisfied
Somewhat satisfied
Neither satisfied nor dissatisfied
Somewhat dissatisfied
Very dissatisfied

FOR PEOPLE WHO TRAVELED (said "Yes" to #3, regardless of their answers to the "Knowledge" questions):
14. In which -- if any -- of the following ways did you change your travel because of the storm?
14a. Did you change your route? No   Yes
14b. Did you change your travel schedule – did you leave earlier or later than usual?
No Yes
14c. Did you use transit such as TRAX, Front Runner train or a bus instead of driving?
No   Yes

15. Did any of the following influence you to change your travel?
15a. Was your decision influenced by the actual weather at the time?
15b. Was your decision influenced by the weather forecast?
15c. Was your decision influenced by known road closures?
15d. Was your decision influenced by known road conditions?

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16. Is there anything else that would have led you to change your travel to avoid driving during the storm? (open ended)

17. WE HAVE A FEW QUICK QUESTIONS ABOUT YOUR BACKGROUND. THESE WILL ALLOW US TO COMPARE OUR SAMPLE TO THE GENERAL POPULATION ALONG THE WASATCH FRONT:

A. In what city do you live?   _____
B. What is your zip code?_____

[Interviewer: Do not read the names – mark the response. If the city is not on the list, type the name in the space above.]

Bacchus ___	Grantsville___	Mills Junction___	Tooele___
Bingham ___	Herriman___	Murray___	West Jordan___
Bluffdale___	Holladay___	North Salt Lake___	West Valley City___
Bountiful___	Hunter___	Park City___	Woods Cross___
Butlerville___	Kearns___	Riverton___	
Centerville___	Kimball Junction___	Salt Lake City___	
Cottonwood Heights___	LakePoint___	Sandy___	
Crescent___	Lark___	Snyderville___	
Draper___	Magna___	South Jordan___	
Farmington___	Midvale___	South Salt Lake___	

C. WHAT IS YOUR AGE? _____
D. ARE YOU MALE OR FEMALE? M   F
E. WHAT IS YOUR ETHNIC GROUP OR RACE?
         WHITE   HISPANIC   AFRICAN AMERICAN   ASIAN   TONGAN/SAMOAN/PACIFIC ISLANDS
                NATIVE AMERICAN   OTHER:
F. ARE YOU EMPLOYED OUTSIDE THE HOME?
     CURRENTLY EMPLOYED FULL OR PART-TIME   RETIRED   NOT EMPLOYED OUTSIDE HOME
G. HOW MANY YEARS OF SCHOOL HAVE YOU COMPLETED? _____
H. ARE YOU CURRENTLY A FULL OR PART-TIME STUDENT? NO   YES
I. FOR HOW MANY YEARS HAVE YOU DRIVEN IN SNOWY CONDITIONS? _____
J. WHAT IS YOUR HOUSEHOLD INCOME PER YEAR? _____

CLOSING: thank you so much for your help. We really appreciate it.

Figure 1F. Survey questions for use in NWS/University of Utah/UDOT study of traveler information sources and decision-making.

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Exhibit G – Example Scenario of Webpage Views

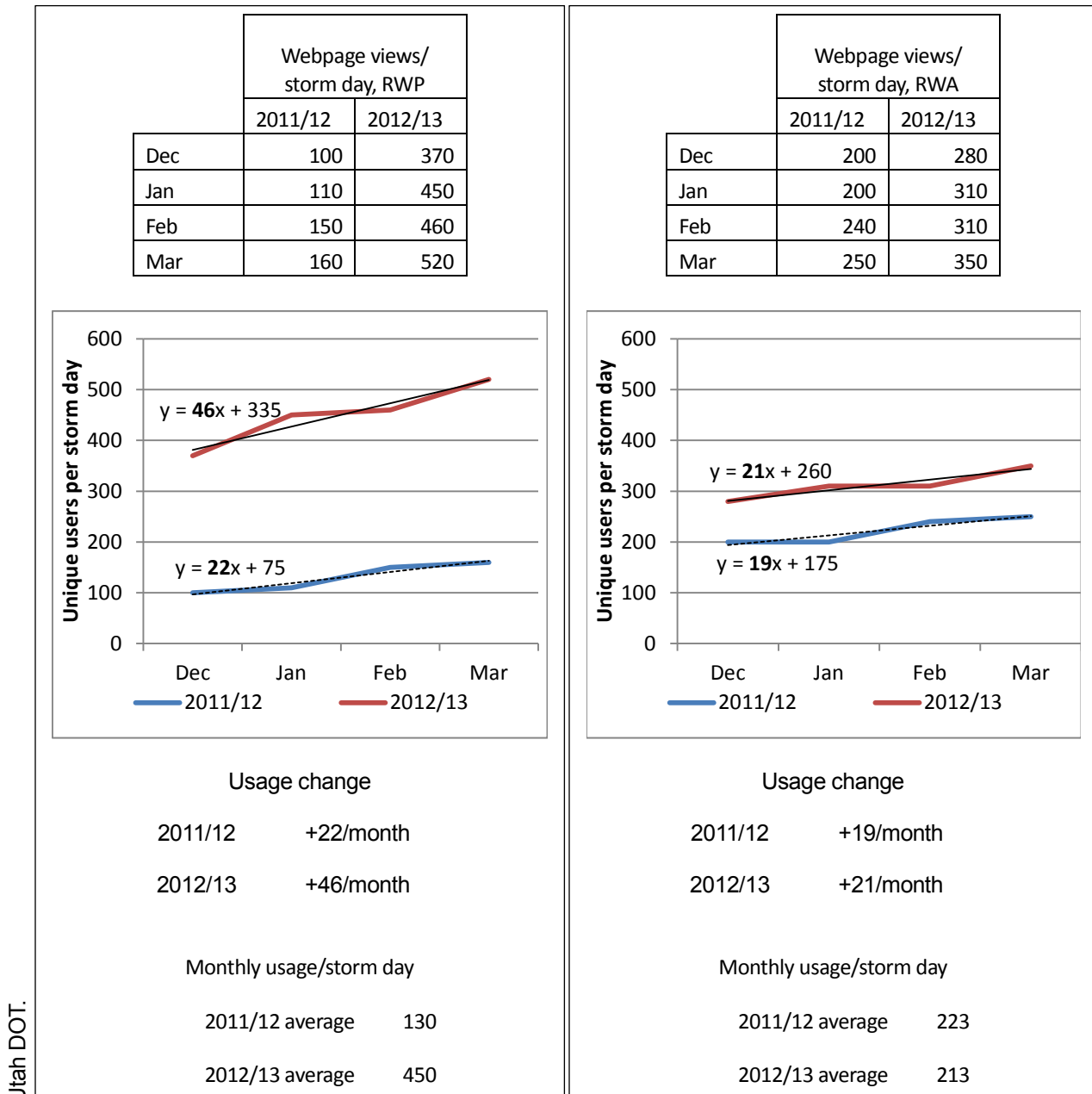Figure G1 is an example usage of the data logged in Table 12 (analysis c, Hypothesis 5).

Webpage views/ storm day, RWP		
	2011/12	2012/13
Dec	100	370
Jan	110	450
Feb	150	460
Mar	160	520

Webpage views/ storm day, RWA		
	2011/12	2012/13
Dec	200	280
Jan	200	310
Feb	240	310
Mar	250	350

Usage change

2011/12	+22/month
2012/13	+46/month

Monthly usage/storm day

2011/12 average	130
2012/13 average	450

Usage change

2011/12	+19/month
2012/13	+21/month

Monthly usage/storm day

2011/12 average	223
2012/13 average	213

Figure G1. Example scenario showing monthly data for Road Weather Page (left) and Road Weather Alert (right)

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For the scenario, line graphs were used to visualize the monthly data, and trendlines were fit to the data. Usage change per month is the first table below the plots, and comes from the trendline equations included in the plots. Hypothesis 5 surmises that slopes will be positive, that is, that usage will increase, specifically during the 2012/13 season. Because RWP information is the focus of the enhancement project, we may also expect to see a stronger increase in monthly RWP usage over the 2012/13 season compared to the increase in RWA usage.

Average monthly usage (per storm day) is calculated for each season and included in the bottom tables in Figure G1. Season-to-season change is included, and the scenario shows that RWP usage increased an average of 320 counts/month (from 2011/12 to 2012/13) and 90 counts/month for the RWA. Again, because RWP information is the focus of the enhancement project, we may expect to see a greater usage increase of the RWP than the RWA.

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U.S. Department of Transportation
ITS Joint Program Office-HOIT
1200 New Jersey Avenue, SE
Washington, DC 20590

Toll-Free "Help Line" 866-367-7487
www.its.dot.gov

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