RITA Intelligent Transportation Systems Joint Program Office

Weather Information Integration in Transportation Management Center (TMC) Operations

Final Report — February 2011
FHWA-JPO-11-058

U.S. Department of Transportation
Research and Innovative Technology Administration

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Produced by Federal Highway Administration Road Weather Management Program for
ITS Joint Program Office
Research and Innovative Technology Administration
U.S. Department of Transportation

Notice

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE (DD MM YYYY)	2. REPORT TYPE	3. DATES COVERED
01/02/2011	Technical	April 2009 – December 2010

4. TITLE AND SUBTITLE
Weather Information Integration in Transportation management Center (TMC) Operations

5a. CONTRACT NUMBER
DTFH61-06-D-00007

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

5d. PROJECT NUMBER

5e. TASK NUMBER
BA07-012

5f. WORK UNIT NUMBER

6. AUTHOR(S)
Chris Cluett and Deepak Gopalakrishna (Battelle), Fred Kitchener (McFarland Management, LLC), Kevin Balke (TTI), and Leon Osborne (Meridian Environmental Technology, Inc.)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Battelle Seattle Research Center
1100 Dexter Avenue North, Suite 400
Seattle, WA 98109-3598

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
United States Department of Transportation
Federal Highway Administration, Office of Operations
1200 New Jersey Ave., SE
Washington, DC 20590

10. SPONSORING/MONITOR'S ACRONYM(S)
HOIT

11. SPONSORING/MONITOR'S REPORT NUMBER(S)
FHWA-JPO-11-058

12a. DISTRIBUTION/AVAILABILITY STATEMENT
This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

12b. DISTRIBUTION CODE

13. SUPPLEMENTARY NOTES
Mr. Roemer Alfelor (COTM)

14. ABSTRACT (Maximum 200 words)
This report presents the results of the third phase of an on-going FHWA study on weather integration in Transportation Management Center (TMC) operations. The report briefly describes the earlier phases of the integration study, summarizes the findings from the implementation and evaluation of an automated weather alert notification system in the Sacramento Regional TMC, and discusses the efforts of four TMCs (Cheyenne, Colorado Springs, Kansas City, Louisiana, and Redding) that used the FHWA self-evaluation guide to identify their weather integration needs and strategies that could be implemented to meet those needs. Four of those TMCs prepared weather integration plans with implementation tasks and schedules. The report tracks their progress toward implementing those strategies and identifies the outcomes and benefits they have achieved to date. Efforts to refine, market and promote the self-evaluation guide are also discussed. Finally, lessons learned and recommendations based on the experiences working with a variety of TMCs are offered to encourage and facilitate greater weather information integration in the future.

15. SUBJECT TERMS
Road Weather Management, Weather Information Integration, Transportation Management Center (TMC), Transportation Operations, Self-Evaluation Guide

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
Unclassified	Unclassified	Unclassified	None	302	Roemer Alfelor
					19b. TELEPHONE NUMBER (202) 366-9242

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39-18

Preface/ Acknowledgements

This report is the third in a series of linked studies, beginning in 2004, that have sought to develop and promote strategies that support Transportation Management Centers (TMCs) in more effectively and proactively responding to a variety of road weather events and conditions that impact traffic and transportation system performance. The content of this report focuses on selected TMCs, their identified needs for weather integration in operations, their selected strategies for meeting those needs, and, in one case, an evaluation of the implementation of one of those strategies – an automated weather alert notification system. The members of the consultant team and authors of this report would like to acknowledge and thank the many individuals in the Road Weather Management Program and in many TMCs around the country who have enthusiastically supported this program with their time, effort, and ideas for improving weather integration. TMC managers and operators spent significant time working through a self-evaluation and planning process, and worked collegially together to help make this program a success.

While many individuals deserve recognition, we want to particularly acknowledge a few individuals for supporting and coordinating efforts to encourage enhanced weather information integration in their TMCs. Jason Sims and Nancy Powell at Kansas City Scout, Brian Simi and Bob McNew at the Sacramento RTMC, Rob Helt and Steve Tobias at the Colorado Springs TMC, Vince Garcia and Kevin Cox at the Wyoming Statewide TMC, and Michael Muffoletto at the Shreveport, Louisiana TMC were all immensely supportive and engaged in this effort. Finally, Roemer Alfelor and Paul Pisano of the Road Weather Management Program have provided their on-going support of this effort with a clear guiding vision of how the proactive use of weather information in TMC operations can improve the performance of our nation’s transportation system and the experience, safety and mobility of all travelers.

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Executive Summary

Background

The Federal Highway Administration's (FHWA) Road Weather Management Program (RWMP) has identified the integration of weather information into the operations of Transportation Management Centers (TMCs) across the country as one of its key objectives. Since early 2004, the RWMP has sponsored a series of three linked studies to develop a concept of weather integration, identify best practices being used by TMCs, and support leading TMCs as demonstration sites for effective integration of weather information in their daily operations. This report describes the third phase of this effort that has focused on the preparation of detailed weather integration implementation plans by selected TMCs, the deployment of integrated systems, and the evaluation of the performance and benefits of those systems. Weather information integration is beginning to take hold but much remains to be done to further raise awareness of the benefits of weather integration and encourage more widespread adoption of weather integration strategies. This report offers several recommendations for additional steps that will need to be taken to more fully accomplish the program objectives.

During the current phase of this weather integration project, assistance was provided to the Sacramento Regional TMC (RTMC) in implementing and evaluating a weather alert notification system based on a strategy identified in their self-evaluation. Three additional TMCs participated in the self-evaluation and integration planning process, including Kansas City Scout, Colorado Springs, Colorado, and the Louisiana statewide TMCs. This study included expanding weather integration activities with additional TMCs, supporting the development and distribution of various marketing strategies and materials, and refining the self-evaluation and planning guidelines to support greater integration in the future. The scope was expanded further to include two interested TMCs (Cheyenne, Wyoming and Redding, CA) that were willing to work with the Guide on their own, with minimal outside support, to conduct the self-evaluation and develop a plan. These efforts allowed both TMC's to identify new levels of weather integration on their own, and proved the ability of the Guide to support such efforts. In addition to these activities, a strategic marketing plan was developed to guide various promotional activities and products in support of weather integration. Finally, the self-evaluation and planning Guide was updated and refined based on the experiences working with the TMCs and their suggestions for improvement. This report describes these and all TMC weather integration activities supported by FHWA to date.

TMC Self-Evaluation, Planning and Implementation Process

Individual deployment plans were prepared in collaboration with the teams formed at each of the TMCs that selected the integration strategies and developed schedules for implementing the integration strategies. With assistance provided through periodic conference calls and several site visits to each participating TMC, their teams worked through the self-evaluation Guide to identify the priority integration strategies that were aligned with their expressed needs to improve operations using integrated weather information. Each TMC cycled through this process several times, making adjustments to their prioritized needs, in order to develop a manageable set of weather integration strategies that seemed feasible for them to implement. The next step was to prepare an integration plan that included an initial outline of the tasks they intended to implement, along with a schedule, in order to achieve the new levels of weather integration they desire. This report provides extensive details for each of these TMCs on their selected priority needs, their target levels of weather integration for each of eleven items of integration, and the specific integration tasks they selected for implementation. The activities of each TMC are noted below:

- **Sacramento, California Regional TMC:** Implemented and evaluated the performance of a weather alert notification system
- **Kansas City Scout TMC:** Integrating weather event forecast information into their Advanced Traffic Management System (ATMS)
- **Colorado Springs TMC:** Conducting a pilot study on winter weather arterial signal timing in one of their city grids
- **Louisiana statewide TMCs:** Completed a comprehensive statewide self-evaluation and integration plan across their four TMCs
- **Wyoming Statewide TMC:** Expanding road weather information sensor coverage and implementing additional variable speed limit notification system in key corridors
- **Redding, California TMC:** Completed their self-evaluation but resource limitations prevented them from completing an integration plan

Evaluation of the Sacramento Regional TMC Weather Alert Notification System

Since 2007 the Caltrans District 3 Regional Transportation Management Center (RTMC) has been participating in the FHWA weather integration study to identify, implement and evaluate strategies to improve the use of weather information in their operations. A separate report documents the full details of a weather alert notification system they developed and the results of an evaluation of this system (Report No. FHWA-JPO-10-063. NTL No. 14969).

The evaluation of the Sacramento RTMC weather alert notification system examined several adverse weather events in detail in order to assess quantitatively how the alert system was performing and how the operators were able to use it in supporting their operational decisions regarding posting of advisory messages. In assessing the RTMC operator responses to these weather events, several indicators were considered:

- Were the warnings and alerts issued appropriately and according to the designated thresholds?
- To what extent was the event covered by messaging to the public?
- Were the appropriate message signs activated based on receipt of alerts and readings from the various sensor sites?
- Were signs deactivated in an appropriate and reasonably timely way?
- Did the operators record information about the event and their decisions in the TMC log?

Key findings included the following:

- The alerts were mostly well timed, indicating the alert notification system was working as planned.
- Messaging coverage was generally good but not complete. However, coverage improved over the duration of the evaluation from December 2009 to April 2010, suggesting that the alerts were helping operators post messages more appropriately.
- A low number of primary message signs had messages posted during the weather event case studies examined, but coverage improved over the course of the evaluation period, presumably due to the operators' increasing familiarity with, and understanding of, the new procedures.
- There were a number of periods after weather events had subsided during which messages were left active longer than needed or desired. The RTMC intends to address this issue with a future system upgrade that will provide operators an alert for the end of an event.
- Operator training is essential for successful weather integration.
- Alert notification procedures need to be clearly and consistently specified.
- Time and resource constraints faced by TMCs affect the performance of an alert notification system.

Strategic Marketing of Weather Integration

As a generalization, weather integration is currently at a relatively low level in most TMCs across the country. In many TMCs it is nonexistent at this time, even though weather, in some form, is affecting transportation safety and mobility everywhere. In addition to the technical tasks that involved working with a small set of TMCs, the strategic marketing efforts focused on activities aimed at increasing the awareness and capabilities of TMCs for integrating weather information in their daily operations.

A strategic marketing plan was developed as part of this study. The plan identified the primary and secondary audiences, the key messages to be conveyed, the challenges to be overcome, and the benefits of weather information integration. The plan also contained an itemized list of activities that supported the marketing efforts. Over the course of the project, various activities were conducted based on the plan.

Overall, the marketing approach resulted in a broad dissemination of the concepts of weather information integration and shared the experiences of the various TMCs engaged in this project. Quantitative numbers are difficult to track and in some cases may be realized only at a later date. The outputs of the marketing and outreach effort identified to date include the following:

- There were over 70 downloads of the Guide following the webinar held June 10, 2010.
- Over 10 presentations were made at various conferences and stakeholder groups on the project by team members and FHWA.
- A Public Roads article published in January 2011 for managing traffic operations during adverse weather events (authored by Roemer Alfelor and David Yang of FHWA) contained a subsection on weather information integration drawing upon results of this study.
- Over 23 TMCs were contacted as part of this study to participate in self-evaluation efforts, and the final participants were selected from that initial list of contacted TMCs.

- A total of six (6) agencies have completed the self-evaluation process. All but one of them have developed integration plans.
- Four (4) TMCs (Sacramento, Kansas City, Wyoming, Colorado Springs) are starting to implement their integration plans/strategies.
- Wyoming TMC and Kansas City Scout have made presentations to other peer groups (ITS Heartland, *Clarus*/Maintenance Decision Support System (MDSS) stakeholder groups) about the benefits of weather information integration and the self-evaluation process.

Ongoing marketing activities for the weather information integration will likely have to overcome a number of challenges. These include challenges associated with TMC willingness to consider weather integration, to invest in the effort and resources required to make integration successful, and to understand and use the Guide effectively. Recognizing these challenges and preparing to overcome them will be essential to a successful marketing effort.

Refinement of the Self-Evaluation Guide

The TMC representatives who participated in this project appreciated the thoroughness of the Guide content, clarity of instructions, and the applicability of the integration strategies presented. Specific feedback was requested and obtained based on the use of the electronic version of the tool. The Guide was updated and improved based on the suggestions from the users.

Technically, the Guide needs a periodic update of the Weather Information Integration Strategies and User Needs. Currently, there are 11 items of integration and 5 levels for each item. These were developed to cover the gamut of information integration options in 2008. With improving technologies and capabilities within TMCs, these strategies need to be reviewed and updated. Similarly, the user needs should be reviewed and updated to reflect the current desires of TMCs.

Accomplishments and Lessons

The accomplishments of many of these TMCs toward the implementation of selected integration strategies are noteworthy and reflect their managements' recognition of the critical impacts of weather on their operations and a strong motivation to better position their operations to take advantage of improved access to weather information.

All these TMCs can point to a common set of important accomplishments achieved through their participation in the weather information integration study, as follows.

- Four comprehensive weather integration plans were prepared that serve not only to guide each TMC's future integration implementation efforts but also to offer clear examples for the benefit of other TMCs of weather integration across a range of strategies and under varying conditions.
- Each TMC established, through participation in the weather integration process, new partnerships, both internal and external to their agency that served to enhance their overall operations, provide benefit to the traveling public, and chart a pathway to improved working relationships in the future.

- TMCs acknowledged the importance of working closely with their counterparts in maintenance. Stronger relationships were established that will encourage collaborative activities and foster active sharing of weather information.
- Awareness was raised at all levels of the DOT organizations involved, from TMC operators and field staff to upper management, of the potential role and value of weather information to enhance the quality and content of traffic operations, and the value of a more proactive stance with regard to managing their systems before, during, and after weather events.

A review of the accomplishments achieved so far by the TMCs that have participated in the weather information integration program over the past six years illustrates a number of “success factors,” lessons, and remaining challenges based on these experiences that can be expected to be relevant to any TMC. Various lessons learned have been identified in prior reports related to this project (Report Nos. FHWA-HOP-06-090. EDL No. 14247; FHWA-JPO-08-058. EDL No. 14438; and FHWA-JPO-10-063. NTL No. 14969), and the potential value of these lessons is tied to creating a wider awareness of the benefits of weather integration and engagement in a process to identify and deploy integration strategies that can improve the operations of TMCs across the country. Broad lessons, common across each of the TMCs in this study, include the following:

- TMC managers are not generally predisposed to seek out new ways to integrate weather information into their traffic operations, and often they are unaware of weather resources that exist within their broader agency. After participating in the self-evaluation and integration planning process, the TMCs in this study recognized the potential value offered by weather integration, but for the most part required considerable assistance in moving forward to incorporate new ways to integrate weather. Self-motivation sufficient to support achievement of real changes in operations based on weather integration, along with a clear understanding of the steps they needed to take, appears to be rare.
- Resources, both financial and staff, constitute a serious challenge to the successful promotion of weather integration in TMCs. While this point has been made a number of times before, it deserves repeating. This is not just a temporary problem associated with particularly difficult economic conditions in many states. TMC personnel are so stretched to fulfill their daily obligations and tasks, that motivating them to take on a new set of tasks and responsibilities, including modifying policies and procedures to support new ways of operating with weather information, is very difficult. Although TMC managers and operators may agree that enhanced weather integration could help them better meet their operational needs and serve their traveling public, weather integration simply does not represent a high enough priority for them among their many tasks.
- While the weather integration study has focused on enhancing TMC operations, the process depends on teamwork not only within the TMC but also with other agencies and stakeholders. Many, though not all, TMCs have separate structures for their operations and maintenance components. The most effective weather integration implies a seamless sharing of information and decision making across operations and maintenance, but the historical arrangements in TMCs often present major institutional and cultural barriers that hinder information sharing. Engagement in the weather information integration project has helped overcome these barriers where they have existed, but the motivation for TMCs and State DOTs to make that happen is lacking.

Recommendations

Four recommendations are offered that focus on the need to build a sustainable weather integration program, effectively promote such a program with documented benefits, refine and maintain a comprehensive tool to evaluate weather information integration in a particular TMC, and identify the most technologically advanced strategies to enhance its capabilities.

1. **Assure Progress and Sustainability of Weather Integration**

   Objective: A goal of the RWMP is to encourage widespread awareness of the value of integrating weather information and systems into TMC operations and progress toward accomplishing that, resulting in a high degree of weather information usage in transportation operations and management.

   Approach: Long-term progress incorporating weather integration into TMC operations must be grounded in a motivated TMC constituency that understands the role of weather integration in the context of WRTM, and not allowed to remain dependent on continued outside assistance. This can be achieved by a multi-pronged strategy that includes the following elements:

   - Follow-up actively on the marketing strategies identified in the current program.
   - Continue to emphasize weather integration as a key component of WRTM.
   - Develop and actively support an institutional strategy within the RWMP to respond to TMC questions and needs with regard to weather integration, including training and networking support.
   - Sponsor one or more workshops with representation from all stakeholders (TMC operations and maintenance; emergency management agencies; software developers; meteorologists; etc.). Include leading weather integrators who can speak from successes.
   - Work closely with and provide support to organizations or groups that include members of the TMC community or work with TMCs, such as the TMC Pooled Fund Program, the TRB, the Institute of Transportation Engineers (ITE), and the American Association of State Highway and Transportation Officials (AASHTO) and their committees and subcommittees that focus on operations and maintenance. Make presentations to these groups based on successful weather integration experiences, encourage them to focus on weather integration, and make them a part of an institutional strategy for sustainable support of weather integration.
   - In the short run, actively support TMCs that express an interest in weather integration, but seek to replace such *ad hoc* responses with an institutionalized, sustainable support infrastructure.
   - Engage each of the major new transportation initiatives to educate and promote with regard to weather integration and include their representatives in the new institutional mechanisms.
   - Seek to overcome the traditional separation and communication barriers between TMC operations and maintenance.

Outcome: The outcome of this recommended set of activities would be a rapid increase of the number of TMCs that undertake weather integration activities in their operations and a growth in sophistication among TMCs that have already made some headway toward weather integration. Weather integration should become mostly self-supporting and no longer require on-going costly outside support in order to motivate adoption.

2. **Identify and Document Evidence of Weather Integration Benefits**

Objective: In order to successfully promote the weather information integration initiative and encourage TMCs to consider weather integration strategies to improve their operations, they need to better understand the potential benefits of implementing these strategies.

Approach: Continue to support Kansas City Scout TMC to finalize and implement their evaluation plan. Continue working with the Wyoming Statewide TMC to complete their integration plan implementation, prepare an evaluation plan, and evaluate their implementation. Continue to work with the Colorado Springs TMC to complete the pilot test of their weather responsive signal timing plans, develop a plan to evaluate the performance of that test, and evaluate the test as a basis for considering expansion throughout their system. Investigate other TMCs that may be enhancing their weather information integration capability (including those that downloaded the Guide and those that are known to be improving their capabilities), prepare a short list of those that are actively implementing a weather integration strategy, and assist them to evaluate their strategy implementation.

Outcome: The outcome of this recommendation will be a set of documented benefits (a report and database) attributable to the implementation of specific weather information integration strategies that could be used to promote and sustain the RWMP's weather integration in traffic operations initiative.

3. **Assure Currency and Relevance of Weather Integration**

Objective: In order to encourage and assure the adoption of weather information integration strategies in TMC operations, the RWMP must facilitate the on-going evolution of integration strategies to "keep pace" with rapid technology and programmatic developments of direct interest to TMC traffic operations and management.

Approach: Prepare a white paper on "Relevance of Weather Information Integration to TMCs" that would:

- Describe advances in ATMS hardware and software that can accept and support improved processing and management of weather information.
- Identify and describe the major current transportation program initiatives and how weather information serves as inputs to those programs along with how the programs can encourage and benefit weather integration strategies. The role of weather information integration needs to be examined in three major emerging programs – Active Transportation Demand Management (ATDM), Integrated Corridor Management (ICM), and the Connected Vehicle initiative. In each of these programs, RWMP should encourage increased understanding and use of weather information. For example, future ICM initiatives around the country should consider a weather-responsive scenario and the ATDM program could focus on linking active traffic management & travel demand management during adverse weather. The RWMP has already started engaging the Connected Vehicle community in considering

vehicles not only as mobile observation platforms but also as receivers of customized spot-specific road weather information.

- The white paper should clarify in practical terms, using real examples, what it means to be proactive with regard to weather integration and how being more proactive offers benefits.

Outcome: This recommendation emphasizes the importance of staying flexible and adjusting weather information integration strategies and rationale to keep current and relevant. Outcomes would include clear, practical examples of how weather integration fits in with the current and projected major transportation program initiatives. The recommended white paper will support further marketing and promotion of weather integration among TMCs by further clarifying its operational benefits.

4. Refine Self-Evaluation Process and Improve Tool

Objective: In order for TMCs to evaluate their current and future potential level of weather integration, they require a tool that is both easy to use and is up-to-date with the most current advances in weather integration strategies.

Approach: Refine and update the weather integration self-evaluation and planning process, improving the tool's usability, and incorporating the most current technological advances in both (the process and the tool). Specifically:

- Review and update the need statements to be more reflective of TMC desires to be more proactive with their responses to road weather conditions.
- Research and update the road weather integration strategies to reflect the most advanced practices being promoted by USDOT and implemented by state DOTs and TMCs. These incorporate the latest communication, programmatic and technological advances, reflect today's best practices, and support new program initiatives such as Connected Vehicles, ICM and ATDM.
- Improve the matrix of needs for weather integration strategies based on the findings of the first two bullets.
- Revise and host the tool on a new and more flexible platform (an Internet-based product).

Outcome: The outcome of this recommendation will be a technically and programmatically current weather integration self-evaluation and planning process, and an easier tool that TMCs can use to investigate and implement possible road weather integration strategies to improve their operations during inclement weather conditions.

Conclusion

This report has demonstrated significant progress towards implementation of advanced levels of weather information integration strategies among many of the TMCs that participated in this study. They have important accomplishments to show for their efforts. The future holds great opportunity to extend the benefits of weather integration to many more TMCs across the country that face weather challenges in their daily traffic operations. This study presented some lessons from the experience of the past six years of the FHWA Road Weather program that highlight the importance of strong self-motivation within TMCs to engage a team composed of operations, maintenance and related agency representatives in weather integration within an environment of constrained resources. The four recommendations presented are directed toward sustaining and enhancing the weather integration program, building additional evidence supporting the benefits of integration, and assuring that the support and tools available to TMCs to help them are effective and up-to-date.

1.0 Introduction and Background

The Federal Highway Administration's (FHWA) Road Weather Management Program (RWMP) has identified the integration of weather information into the operations of Transportation Management Centers (TMCs) across the country as a key objective. Since early 2004, the RWMP has sponsored a series of three linked studies to develop a concept of weather integration, identify best practices being used by TMCs, and support leading TMCs as demonstration sites for effective integration of weather information in their daily operations. This report describes the third phase of this effort that has focused on the preparation of detailed weather integration implementation plans by selected TMCs, the deployment of integrated systems, and the evaluation of the performance and benefits of those systems. Weather information integration is beginning to take hold but much remains to be done to further raise awareness of the benefits of weather integration and encourage more widespread adoption of weather integration strategies. This report offers several recommendations for additional steps that will need to be taken to more fully accomplish the program objectives.

1.1 Project History

Phase I Integration Study: 2004-2005. The first study in the weather integration series began with an investigation of the needs and opportunities for the integration of emergency and weather elements in TMC operations, along with an exploration of the concepts, methods and potential benefits of integration to improve operations. Thirty eight TMCs across the country were contacted, and ten of them were visited. These TMCs demonstrated current best practices in the integration of weather and emergency information and systems. The final report from this study[1] summarized how weather and emergency information and decision-support systems were being integrated in these TMCs. In order to better organize and present the activities of these TMCs, further background research was conducted to help define and clarify the concept of integration. Potential benefits of integration were identified, including the following:

- Improved access to all regional information using compatible, standards-based systems over reliable communication systems.
- Ability to coordinate and pool resources to accomplish operations not currently possible.
- Improved clarity of roles and ability to communicate both current operations and future investments.
- More timely and accurate information provided to the traveling public, thereby increasing customer safety and satisfaction.
- Better prepared TMC operators to address adverse weather on the transportation system in terms of appropriate staffing and implementation of traffic advisories and control strategies.

[1] Cluett, C., Kitchener, F., Shank, D., Osborne, L., and Conger, S. (2006). *Integration of Emergency and Weather Elements into Transportation Management Centers* (Report No. FHWA-HOP-06-090. EDL No. 14247). Washington, DC: Federal Highway Administration. Available at: http://ntl.bts.gov/lib/jpodocs/repts_te/14247_files/14247.pdf

Nine recommendations were offered to help encourage and enhance weather integration. These included enhancing awareness of the value of weather information integration, promoting the concept and best practices, self-evaluation of integration needs, developing integration guidelines, improving communication between the weather and transportation communities, fostering research on how weather integration can help TMC operations, and encouraging uniform practices of integration across TMCs.

Phase II Integration Study: 2006-2008. The second study[2] in the weather integration series built upon the recommendation from the first study that TMCs "should conduct a self-evaluation to help identify the most effective integration solutions and guide their deployment." A self-evaluation guide was developed, using Microsoft Access, to assist TMCs in identifying their weather integration needs and matching their high priority needs with appropriate, implementable integration strategies. Also included was an outline for preparing a comprehensive integration plan. This study was centered on two TMCs (Sacramento, CA and Milwaukee, WI) that formed multi-agency teams to identify practical, implementable weather information integration strategies. Based on the experiences of these TMCs, lessons learned were presented, and suggestions for improving the Guide were incorporated into an updated version that was made publically available on the RWMP website.

Eleven recommendations were offered, based on the experience working with these TMCs, primarily related to education and training, and further implementation and refinement of the self-evaluation process supported by the Guide. Underlying these recommendations are a few common themes that include the need for:

- key individuals in the state Departments of Transportation (DOTs) and TMCs to champion weather integration,
- motivation to engage in a partnership among DOT management, TMC operations and maintenance, representatives of related agencies (e.g., emergency response, highway patrol), and the meteorological community,
- an evidence base that demonstrates the benefit-cost advantages of integration, with evaluation and promotion of the value of integration based on that evidence, and
- resources (staff, money and materials) to fully support weather integration implementation.

Phase III Integration Study: 2009-2011. The third study in the weather integration series is the subject of this report. During this latest period, the consultant team assisted the Sacramento Regional TMC (RTMC) in carrying out and evaluating a weather alert notification system that they had implemented, based on a strategy identified in their self-evaluation. Three additional TMCs volunteered to participate in the self-evaluation and integration planning process, including Kansas City Scout, Colorado Springs, Colorado, and the Louisiana State TMCs. The scope of this phase of the study included expanding weather integration activities with additional TMCs, supporting the development and distribution of various marketing strategies and materials, and refining the self-evaluation and planning guidelines to support greater integration in the future. After this phase was underway, the scope was expanded further to include two interested TMCs that were willing to work with the Guide on their own,

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[2]Cluett, C., Gopalakrishna, D., Balke, K., Kitchener, F., and Osborne, L. (2008). *Integrating Weather in TMC Operations.* (Report No. FHWA-JPO-08-058. EDL No. 14438). Washington, DC: Federal Highway Administration. Available at: http://ntl.bts.gov/lib/30000/30900/30940/tmc_wx_integration_report_11_17_08.pdf

with minimal outside support, to conduct their self-evaluation and develop a plan. This served as a test of the ability of the Wyoming Statewide TMC and the Redding, California TMC to achieve new levels of weather integration on their own and the ability of the Guide to support those efforts. This report describes the conduct and results of this third phase study.

1.2 Policy Background for Weather Information Integration

Prior to the first phase of the weather information integration studies, the FHWA sponsored a study to develop a concept of operations for managing weather events.[3] This concept is grounded in three basic operational objectives: maintain and improve safety, maintain and improve mobility, and improve agency productivity. According to the study, to achieve these objectives with regard to operating under adverse weather conditions, a transportation agency gathers information and seeks to predict or anticipate potential impacts, and employs mitigation strategies either in anticipation or in response to impacts. The report concludes that, while weather-responsive traffic operations offers great value to managers, "this concept will be enhanced by [the] establishment of mechanisms for improved coordination within transportation agency divisions and between transportation agencies and other key response agencies (p. 4-1)." Right after this study, the National Academy of Science conducted a study that has served to guide the RWMP in framing its research agenda. This study recognized the importance of inter-agency coordination in support of weather integration and provided recommendations for research to "provide a framework to engage the transportation and weather communities [to help them] capitalize on existing capabilities and take advantage of opportunities for advances (p. 2)."[4]

Recognizing the unacceptably high safety and mobility impacts of severe weather on the transportation system, the RWMP established a roadmap of programmatic initiatives in an effort to help state DOTs and affiliated agencies mitigate the adverse effects of weather. One of those important initiatives has included the weather information integration studies. The RWMP created a framework for its Weather Responsive Traffic Management (WRTM) program that illustrates how weather information integration dovetails with the other key elements in the program (Figure 1).

The starting point for the weather integration project was to identify TMCs engaged in best practices with regard to taking weather into account in their operational decision-making and build from that base to encourage more TMCs to adopt weather integration strategies. Further work has clarified both the potential benefits of integration and the challenges faced in achieving that goal. A common thread throughout this work is the recognition of the success factors of having a combination of an informed and motivated operational team along with the identification of clear integration strategies and the resources to support their implementation.

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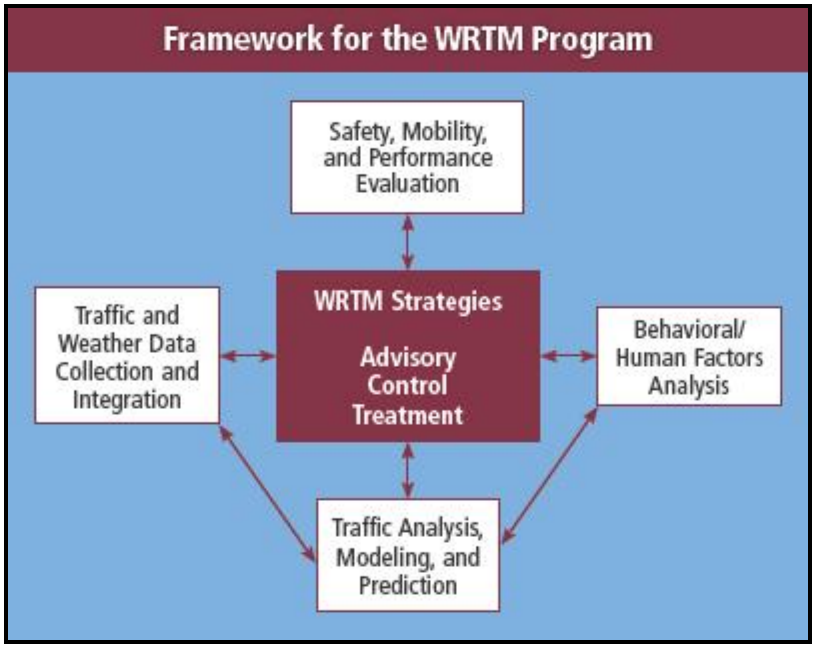
[3] Federal Highway Administration. 2003. *Weather-Responsive Traffic Management: Concept of Operations.* Draft report prepared by Cambridge Systematics, Inc. (January 10).
[4] National Research Council of the National Academies, Committee on Weather Research for Surface Transportation: The Roadway Environment. 2004. *Where the Weather Meets the Road: A Research Agenda for Improving Road Weather Services.* Washington, D.C.: The National Academies Press.

Figure 1. Framework for the WRTM Program



Source: FHWA

Based on the experience to date, successful strategies have been identified and deployed, but much more needs to be done to extend the benefits of weather information integration to a significant number of TMCs in the country. Effective integration of weather information and services into TMCs will facilitate and support:

- Well-informed maintenance and operational staff who understand the effects of weather events on road conditions and transportation system performance, along with the value of a coordinated road weather management system.
- Timely and more pro-active operational decision making, including the ability to effectively respond to forecast weather events and prepare before serious problems arise.
- Operational understanding of available weather integration tools and how to use them effectively in a TMC.
- The value of a weather perspective embedded in the TMC concept of operations and accepted by management as the preferred way of conducting the functions of the TMC.
- A weather responsive performance assessment system that monitors TMC performance and supports a continuous improvement process.

1.3 Contents of this Report

This report discusses the activities conducted as part of Phase III of the weather information integration study. The following sections are covered:

- Section 3.0: Describes the selection criteria and process followed to identify prospective TMCs to participate in self-evaluation of weather integration needs and the development of an integration plan based on identified integration strategies. The TMCs were divided into two tiers, Tier 1 receiving extensive support in working with the Guide and Tier 2 agreeing to work mostly on their own.

- Section 4.0: Describes the planning process at the Tier 1 and Tier 2 sites.
- Section 5.0: Describes the implementation and evaluation of a weather alert notification system at the Sacramento RTMC.
- Section 6.0: Describes a strategic marketing plan and measures of integration performance.
- Section 7.0: Describes modifications to the Self-Evaluation and Integration Planning Guide that were made, based on experiences working with various TMCs and the feedback they provided for Guide improvement.
- Section 8.0: Describes the overall accomplishments of the weather integration work, including the lessons learned.
- Section 9.0: Provides four recommendations for further program consideration based on the cumulative experiences of the past seven years of weather integration work.

2.0 Identifying Candidate TMCs for Weather Information Integration

This section describes the process to select TMCs for participation, the TMCs selected, and the specific plans developed for each TMC to conduct the self-evaluation. The selection and planning processes were carried out to:

1. Identify criteria by which TMC's would be evaluated and selected for project participation
2. Identify candidate TMC's and recommend a limited number to participate
3. Define a project deployment plan for following up with each TMC selected

The deployment plan was completed in April 2009 as an internal project document. It contained a list of all TMCs contacted and their levels of interest in weather information integration.

Five TMC candidates were selected because it was felt they would significantly benefit from enhancing weather information integration in their operations and were interested and motivated to participate. These candidate TMCs were grouped into two tiers and received different levels of assistance from the consultant team to work through the Guide and develop a weather integration plan.

The five selected TMCs are a good representation of TMCs across the country with varied geographic locations, types of operations, and weather conditions that impact their respective transportation systems. Also, the TMCs varied in their current levels of weather integration and therefore offered good opportunities to identify and evaluate different integration strategies.

2.1 TMC Site Selection Process

The goal of the selection process was to identify TMCs that the consultant team could support to 1) conduct a self-evaluation that is responsive to their needs and results in weather integration strategies suitable for deployment, and 2) prepare a weather integration plan.

2.1.1 Selection Criteria

Selecting the most appropriate TMCs was essential to the success of the project. The consultant team established and used the following criteria to screen a long list of potential TMCs and select those that would receive assistance to work through the Guide and develop an integration plan.

A. **Region** – a balanced representation of TMCs across the country
B. **Operations** – variety of operational types with at least one focused on arterial management
C. **Weather impacting transportation system** – variety of weather types
D. **Level of weather impacts on transportation system** – significant weather impacts
E. **Current level of availability and use of weather information in operations** – range from low to high to reflect the circumstances of TMCs across the country

F. **Interest in integrating weather information into TMC operations** – strong interest in enhancing their level of weather integration
G. **Potential to be national case study example of weather information integration** – high potential to serve as a national example
H. **Extent of institutional and/or technological barriers** – indication of low barriers to weather integration
I. **Willingness to participate in the project** – Strong willingness to participate

It was important that a TMC indicated a strong interest in participating in the process; however, the focus was on identifying TMCs that could demonstrate the benefits of integration and were diverse in the types of weather integration they sought and the weather and operational characteristics of their TMC location in order to enhance the potential marketing insights and benefits. Additionally, diverse types of transportation operations were also important, with the goal of including at least one TMC that managed an arterial network. Table 1 summarizes the selection criteria and defines the anticipated variation in each of the criteria and desired outcome for each of the TMCs. Recognizing that it would be difficult to find TMCs that are ideal with respect to every criterion, the selection process sought to identify TMCs that most closely met the project goals.

Table 1. TMC Weather Integration Assessment, Plan Development and Implementation Selection Criteria

A	B	C	D	E	F	G	H	I
Region	Operations	Weather impacting transportation system	Level of weather impacts on transportation system	Current level of availability and use of Wx information in operations	Interest in integrating Wx information into TMC Operations	Potential to be national case study example of weather information integration	Extent of institutional and/or technological barriers	Willingness to participate in the project
Anticipated variation in each of the criteria								
West, North, South, East, Northwest, Southwest, Northeast, Southeast, North central, South central.	Regional or statewide. Freeway, arterial or both. Urban or rural	Snow, ice, freezing rain, heavy rain, flooding, hurricanes, blowing dust/sand, blizzards.	High, Medium, or Low. Judgment of interviewer based on response to questions.	High, Medium, or Low. Judgment of interviewer based on response to questions derived from the integration matrix.	Strong, mild, or no interest. Types of improvements that they are interested in and expected benefits.	High, Medium, or Low. Judgment of interviewer based on response to questions.	High, Medium, or Low. Judgment of interviewer based on response to questions.	Willing or not willing.
Desired outcome of TMC selection process								
Regional balance	Variety of operational types. At least one focused on managing arterials	Variety of weather types	Significant (high) weather impacts	Mix of low to high use levels for Wx information	Strong interest in enhancing Wx integration; variation in desired types of Wx integration	High potential to serve as national example	Low barriers to Wx integration	Strong willingness to participate in self-assessment and plan development.

2.1.2 Identifying Candidate TMCs

The process to identify candidate TMCs began with the development of a list of potential candidates, considering the selection criteria described above and the following components:

- Review of previous TMC lists from the earlier phases of the weather integration studies. Some TMCs were eliminated and others were carried forward based on how well they met the criteria.
- Input from FHWA and the consultant team regarding their experience and knowledge of TMCs and their operations.
- Interest expressed by TMC Pooled Fund members during a presentation to this group in Nashville, TN on July 15, 2008. Some members who represent member states said they were interested in further discussions and were subsequently contacted. They suggested several TMCs in their states that were added to the list.
- Response to the 2007 Intelligent Transportation System (ITS) Infrastructure TMC Survey[5]. Several appeared to be good candidates and were added to the list.

This resulted in a list of thirty-nine potential TMCs. Of the original thirty-nine, the consultant team discussed the potential project participation with personnel from twenty-three TMCs. Once enough TMCs were identified, the consultant team stopped contacting TMCs.

The consultant team contacted the TMCs by phone to learn more about their operations and interest level, asking a set of questions based on each of the selection criteria to determine their suitability for participation. The results of these discussions and recommendations of TMCs to work through the self-evaluation and integration planning processes are presented in the next section.

2.1.3 Selection of the Most Promising TMCs

Based on the responses during the phone interviews, the TMCs were categorized as follows:

- Four TMCs indicated that they did not require the use of weather information and therefore were not interested in participating. This may have been because weather did not play a significant role in traffic management challenges faced by the TMC or that weather information was handled by another organization (such as maintenance) and the TMC did not perceive a need for the information.
- Five TMCs indicated that their operations did require the use of weather information, but they felt they had what they needed and were not planning to enhance their weather integration capabilities.
- Five TMCs expressed an interest in enhancing their current level of weather integration, but felt they could not devote the time and resources required to participate in the project at this time.
- Four TMCs were interested in participating, but after discussing their operations with the consultant team it was apparent that they did not sufficiently meet the selection criteria.
- Five TMCs expressed a high level of interest in enhancing their level of weather integration in their operations. Based on the interviews, the consultant team determined they best fit the selection criteria.

[5] Research and Innovative Technology Administration. (2007). *ITS Deployment Statistics Database: Survey and Results.* Washington, DC: U.S. Department of Transportation. Available at: www.itsdeployment.its.dot.gov.

These five TMCs, along with their strong interest, exhibited the right conditions to benefit from enhanced weather integration. Additional phone conversations were conducted with these TMCs to learn more about the possibilities of their involvement and to ensure their full commitment to the self-evaluation process and development of an integration plan centered around their selected weather integration strategies (from the Guide).

This project was scoped to originally identify and work with three TMCs (Tier 1). In order to be responsive to the interests of the remaining qualified TMCs, the consultant team, in consultation with FHWA, recommended adding a second group (Tier 2) of TMCs to the project. These two tiers are defined as follows:

Tier 1: Three TMC will receive assistance from the consultant team as defined by the original project scope, including 3-4 visits to their location to work through the self-evaluation and develop an Integration Plan.

Tier 2: Up to three additional TMCs will be provided a copy of the Guide and general instructions to get started with limited assistance from the consultant team in the way of phone conversations to answer questions. No on-site visits will be planned.

The Tier 2 concept was new to the project, and offered an opportunity to determine whether TMCs can be expected to seek out the Guide on-line and successfully carry out a self-evaluation and planning process essentially on their own and without assistance. These Tier 2 TMCs would also serve as alternates to the Tier 1 group should an event arise that would prevent one of them from completing the project, and the opportunity to expose more TMCs to the Guide and obtain further input regarding its usefulness.

Table 2 identifies the five TMCs selected for project participation and their responses to each of the selection criteria.

The three TMCs recommended for Tier 1 involvement and a brief explanation of their site characteristics are as follows:

Colorado Springs Regional TMC – This TMC manages both the freeway system and arterial network for the regional area surrounding Colorado Springs, Colorado. This includes 562 signals. It experiences heavy winter snow and ice conditions, severe thunderstorms with heavy rains, dense fog, and potential for flooding. It currently exhibits a low level of weather integration and is very interested in enhancing its capabilities in this area. The TMC possesses the potential to explore weather integration strategies to better manage traffic flow on arterials during winter storm conditions with revised signal timing plans. This site offers an opportunity to show how smaller regional TMCs can benefit from enhanced weather integration strategies.

Table 2. Five Selected TMCs and their Responses to the Selection Criteria

TMC	Region	Type of operation	Weather impacting transportation system	Level of weather impacts on transportation system	Current level of availability and use of weather information on operations	Interest in integrating weather information into TMC operations	Potential to be national case study example of weather information integration	Extent of institutional and/or technological barriers	Willing-ness to participate in the project	Comments
TMCs RECOMMENDED FOR TIER 1 PROCESS										
Colorado Springs, CO	West Central	Regional, mostly urban, freeway/ arterials	Snow, ice, heavy rain, flooding, and fog	Medium/High	Low	Strong – want to know about what's possible. Potential for signal system application	High – regional freeway and arterial managemen;. Signal control functions with Wx. Info. Winter Wx.	Low	Willing	Potential to demonstrate proactive control of arterial signals and modification of timing patterns during winter storm events. Also, a relatively small TMC that can serve as a good example for many smaller systems around the country
Kansas City, KS	Central	Multi-state, urban, freeway	Rain, flooding, tornadoes, high winds, some snow	High	Medium	Strong – need better prediction capabilities	High – integration of weather information across two states in one TMC. All freeway, mostly advisory functions.	Low	Willing	Potential to demonstrate weather integration in TMC operations of an extensive Interstate system across a large metropolitan area involving a two-state coalition.

Table 2. Five Selected TMCs and their Responses to the Selection Criteria (continued)

TMC	Region	Type of operation	Weather impacting transportation system	Level of weather impacts on transportation system	Current level of availability and use of Weather information on operations	Interest in integrating weather information into TMC operations	Potential to be national case study example of weather information integration	Extent of institutional and/or technological barriers	Willing-ness to participate in the project	Comments
Louisiana – 3 regional TMCs in Shreveport, Baton Rouge, and New Orleans; and another statewide TMC located in Baton Rouge.	South	Regional and statewide, freeways	Heavy rain, flooding, hurricane, tornadoes	Medium to High	Low	Strong – Need better prediction capability and location specifics. Need better preparation details and timing.	High – Integration of weather information across four TMCs encompassing the entire state. Mostly advisory functions, but some control related to evacuations.	Low	Willing	Potential to demonstrate integration of weather information among four separate TMCs across the state of Louisiana. Also, potential to address unique weather impacts due to tornadoes and hurricanes that may be of interest to other southern states.
TMCs RECOMMENDED FOR TIER 2 PROCESS										
Redding, CA	West	Large District, rural, freeway	Heavy rain, snow, fires, strong wind	High	Low	Strong – need for reliable forecasting	High – mountainous road conds with severe weather. Chain rqmts is primary control function.	Medium	Willing	Potential to demonstrate improved traveler information and safety warnings within a large rural region that experiences varied weather conditions.

Table 2. Five Selected TMCs and their Responses to the Selection Criteria (continued)

TMC	Region	Type of operation	Weather impacting transportation system	Level of weather impacts on transportation system	Current level of availability and use of Weather information on operations	Interest in integrating weather information into TMC operations	Potential to be national case study example of weather information integration	Extent of institutional and/or technologic al barriers	Willing-ness to participate in the project	Comments
Wyoming DOT	West	Statewide, rural, freeway	Snow, ice, strong winds, blowing snow	High	Medium	High – extremely rural, statewide center, severe winter weather	High – want to integrate weather info with new variable speed signs (control)	Low	Willing	Potential to demonstrate improved management of a statewide network of rural Interstates and state highways that experience extreme winter weather conditions, frequent road closures and strong winds.

Kansas City Scout Regional TMC – This TMC manages 125 miles of Interstate highways in the Kansas City metropolitan area across a two-state region. The TMC is jointly managed by Missouri and Kansas and is staffed by representatives from both states, with a management structure that alleviates institutional barriers that may otherwise be present. The area experiences heavy rain, flooding, tornadoes, high winds, and snow. The TMC exhibited a medium level of weather integration and was very interested in enhancing its capabilities in this area. It represents a large metropolitan area with numerous Interstate highways that experience heavy congestion and increased traffic crashes during severe weather conditions.

Louisiana Regional and Statewide TMCs – The state of Louisiana has four TMCs – three regional TMCs in Shreveport, Baton Rouge, and New Orleans (operational in Sept 2009); and a statewide TMC located in Baton Rouge. They experience heavy rain, flooding, hurricanes, and tornadoes. Although their use of weather information was expanding and their evacuation preparations had improved significantly since hurricane Katrina, they were at a relatively low level of weather integration. They were very interested in enhancing their weather integration capabilities. They represent an entire state with multiple TMCs with the potential to integrate weather in each TMC as well as between the TMCs and at a statewide level.

The two additional TMCs recommended for Tier 2 involvement and a brief explanation of their conditions are as follows:

Redding, California Caltrans District 2 TMC – This Caltrans District-wide TMC located in Redding, California (north central) manages all the California state highways and Interstates in a large seven county area. The area experiences heavy rain, flooding, snow at the higher elevations, fires, and high winds. They exhibited a low level of weather integration and were very interested in enhancing their weather operations capabilities. They represent a large geographic rural area with numerous state highways and Interstates that experience a variety of severe weather conditions that affect the highways and the safety of the traveling public.

Wyoming Statewide TMC – The state of Wyoming has one TMC in Cheyenne that manages the Interstates and all state highways that include the majority of the transportation network throughout this rural state. They primarily experience heavy snow, high winds, and blowing/drifting snow throughout the state. Interstate 80 is a major commercial goods transport corridor that traverses the lower portion of the state. The TMC exists primarily to address severe weather conditions that frequently require closure of important Interstates and state highways throughout the state during the winter months. They demonstrated a medium level of weather integration and were very interested in enhancing their weather integration capabilities. They represent a rural statewide TMC with severe weather conditions that significantly impact travel within the state.

2.2 Deployment Plans for Selected TMCs

The three recommended Tier 1 TMCs received extensive support from the consultant team as they implemented the self-evaluation and integration planning process. The two Tier 2 sites went through the same process mostly on their own, with a reduced level of interaction with the consultant team. During this process, the consultant team’s objectives were as follows:

- Assist both the Tier 1 and Tier 2 TMCs to increase their level of understanding of the use of road weather information and how it can be better integrated with TMC operations.

- Assist both the Tier 1 and Tier 2 TMCs to gain a complete understanding of the Weather Integration Self-Evaluation and Planning Guide and how it can be used to identify possible strategies to enhance weather integration.
- Identify Tier 1 and Tier 2 TMCs that would be willing to promote the use of the Guide with their counterparts at other TMCs across the country and speak about their experiences and expectations for future benefits.
- Working closely with the Tier 1 TMCs, provide assistance in carrying out their self-evaluation, identifying weather integration strategies, and developing an Integration Plan.
- Provide limited assistance to the Tier 2 TMCs and track their progress with the Guide to determine what is needed for a TMC to use the Guide on their own, without extensive help from external sources.
- Derive feedback from the TMCs about possible future enhancements to improve the content and usefulness of the Guide based on the experience of both the Tier 1 and Tier 2 TMCs working with the Guide.

2.2.1 Tier 1 TMCs

The consultant team worked closely with each of the Tier 1 TMCs to work through the self-evaluation Guide, identify weather integration strategies, and develop an Integration Plan. As part of this assistance, the consultant conducted up to four site visits to provide structured support to the TMCs, as follows:

- Site visit #1: Introduce the process and the Self-Evaluation Guide and review each step and the data needed to conduct the self-evaluation. Identify the right mix of TMC staff to work through the Guide. Identify a schedule for completing the self-evaluation and plan development.
- Site visit #2: Review the results of the self-evaluation and the candidate weather integration strategies resulting from the self-evaluation. Review the Weather Integration Plan outline, and identify all the needed information to complete the Integration Plan.
- Site visit #3: Review the draft Weather Integration Plan prepared by the TMC and support the completion of the Plan.
- Site visit #4: (optional): Review the final Weather Integration Plan and discuss other input and feedback to improve the Guide and the explanation of the process. Depending on the progress made by the TMC, this final site visit may not be needed, and its activities would be incorporated into the third visit.

In addition to these site visits, the consultant conducted monthly (or as needed) phone discussions with the TMC lead contact to review progress, answer questions, and provide assistance to ensure the TMC maintained focus on the tasks and adhered to the agreed upon schedule.

Specific deployment plans were prepared and focused on each TMC that defined the activities to be conducted as part of the project tasks. Table 3, Table 4 and Table 5 provide the deployment plans. Some schedule alterations were made to ensure a smooth project implementation.

Table 3. Weather Information Integration Deployment Plan Overview: Colorado Springs, Colorado

Tier 1 TMC	Colorado Springs Regional TMC

General Description:

This regional TMC manages both the freeway system and arterial network for the area surrounding Colorado Springs, Colorado. This includes 30 miles of Interstate 25 and 564 signals. They experience heavy snow and ice conditions, severe thunderstorms with heavy rains, dense fog, and potential for flooding. They currently exhibit a low level of weather integration and are very interested in enhancing their capabilities in this area.

Primary Contact:	Phone: 719-385-7603
Rob Helt, TMC Manager	Email: rhelt@springsgov.com

Others Involved:

CDOT representatives from Golden, CO office; Colorado Springs Street Maintenance personnel; city Emergency Operations Center (EOC)

Planned Activities and Tentative Schedule

Activities	Preliminary Dates
Visit 1: Kickoff and introduction meeting	4/22/09
TMC builds internal team	5/1/09
TMC completes self-evaluation and identifies Wx integration strategies	6/12/09
Visit 2: Review strategies and discuss integration planning process	6/24/09
TMC team finalizes strategies	6/26/09
TMC team prepares draft of Integration Plan	8/21/09
Visit 3: Review draft Integration Plan	8/26/09
TMC team finalizes Integration Plan	9/15/09
Visit 4 (optional): Review final Integration Plan	9/15/09
TMC completes Integration Plan; provides feedback on use of Guide	9/25/09

Project Approach/Weather Integration Opportunities:

The Colorado Springs Regional TMC will work with representatives from CDOT and the city Street Maintenance Division to conduct the self-evaluation and develop an Integration Plan. They will explore weather integration strategies to better manage their traffic flow on arterials during winter storm conditions with revised signal timing plans. They represent the opportunity to show how smaller TMCs can benefit from enhanced weather integration.

The Consultant's Planned Involvement:

The consultant team will work through the Guide with the Colorado Springs Regional TMC to help them develop their Integration Plan. Three or four visits to Colorado Springs to discuss progress and provide advice will be conducted during the course of the project. Advice may include technical information and examples from other TMCs about specific weather integration strategies that are of interest to Colorado Springs.

Table 4. Weather Information Integration Deployment Plan Overview: Kansas City, Missouri

Tier 1 TMC	Kansas City Scout Regional TMC
General Description: This TMC manages 125 miles of Interstate highways in the Kansas City metropolitan area across a two-state region. The TMC is jointly managed by Missouri and Kansas and is staffed by representatives from both states, with a management structure that alleviates institutional barriers that may otherwise be present. The area experiences heavy rain, flooding, tornadoes, high winds, and some snow. They currently exhibit a medium level of weather integration and are very interested in enhancing their capabilities in this area. They represent a large metropolitan area with numerous Interstate highways that experience heavy congestion and increased traffic crashes during severe weather conditions.	
Primary Contact:	**Phone:** 816-622-0528 (cell)
Jason Sims, TMC Manager	**Email:** Ervin.sims@modot.mo.gov
Others Involved: Nancy Powell – 816-347-2285	
Planned Activities and Tentative Schedule	
Activities	**Preliminary Dates**
Visit 1: Kickoff and introduction meeting	5/27/09
TMC builds internal team	5/29/09
TMC completes self-evaluation and identifies Wx integration strategies	6/26/09
Visit 2: Review strategies and discuss integration planning process	7/8/09
TMC team finalizes strategies	7/10/09
TMC team prepares draft of Integration Plan	8/28/09
Visit 3: Review draft Integration Plan	9/2/09
TMC team finalizes Integration Plan	9/15/09
Visit 4 (optional): Review final Integration Plan	9/16/09
TMC completes Integration Plan; provides feedback on use of Guide	9/25/09
Project Approach/Weather Integration Opportunities: Nancy Powell will lead a group from the Kansas City Scout TMC that will conduct the self-evaluation using the Guide and develop an integration plan. An opportunity exists to enhance their capability to display pertinent weather information on their Advanced Traffic Management System (ATMS) screens and regional maps.	
The Consultant's Planned Involvement: The consultant team will work through the Guide with the Kansas City Scout TMC to help them develop their weather integration plan. Three or four visits to Kansas City, MO to discuss progress and provide advice will be conducted during the course of the project. Advice may include technical information and examples from other TMCs about specific weather integration strategies that are of interest to Kansas City Scout.	

Table 5. Weather Information Integration Deployment Plan Overview: Louisiana

Tier 1 TMC	Louisiana State TMCs
General Description: The state of Louisiana has four TMCs – 3 regional TMCs in Shreveport, Baton Rouge, and New Orleans (to be operational in July 2009); and a statewide TMC located in Baton Rouge. They experience heavy rain, flooding, hurricanes, and tornadoes. Although their use of weather information is expanding and their evacuation preparations have improved significantly since hurricane Katrina, they are currently judged to be at a low level of weather integration.	
Primary Contact: Michael Muffoletto (Shreveport TMC)	**Phone:** 318-549-8347 **Email:** michaelmuffoletto@ladotd.gov
Others Involved: Adam Moncivaez (Statewide TMC) – 225-379-2563; Bryan Costello (Baton Rouge TMC) – 225-362-9935; Rachel East (New Orleans TMC) – 225-379-2576	
Planned Activities and Tentative Schedule	
Activities	**Preliminary Dates**
Visit 1: Kickoff and introduction meeting	3/17/09
TMC builds internal team	4/1/09
TMC completes self-evaluation and identifies Wx integration strategies	4/13/09
Visit 2: Review strategies and discuss integration planning process	4/28/09
TMC team finalizes strategies	5/1/09
TMC team prepares draft of Integration Plan	6/30/09
Visit 3: Review draft Integration Plan	7/10/09
TMC team finalizes Integration Plan	7/24/09
Visit 4 (optional): Review final Integration Plan	7/31/09
TMC completes Integration Plan; provides feedback on use of Guide	7/31/09
Project Approach/Weather Integration Opportunities: Each of the four TMCs will work through their self-evaluation independently and then meet to discuss the results and identify common and unique weather integration strategies. Working closely with the consultant, they will select a set of weather integration strategies and develop an Integration Plan that outlines how they would proceed to implement the selected strategies in the future. During the process, they will document any possible improvements to the Guide and provide to the consultant.	
The Consultant's Planned Involvement: The consultant team will work through the Guide with the Louisiana TMCs to help them develop their weather integration plan. Three or four visits to Baton Rouge to discuss progress and provide advice will be conducted during the course of the project. Advice may include technical information and examples from other TMCs about specific weather integration strategies that are of interest to Louisiana.	

2.2.2 Tier 2 TMCs

The consultant team provided limited assistance to the two Tier 2 TMCs to carry out their self-evaluations and develop weather their integration plans. These TMCs were asked to identify weather integration strategies and develop an integration plan on their own, without external support. As part of this limited assistance, the consultant visited each site, conducted up to four phone conversations with the TMC lead contact to review progress, answered questions, and provided limited assistance to ensure the TMC was maintaining focus on the tasks and keeping with the schedule, as follows:

- Phone conversation #1: Introduce the process and the self-evaluation Guide. Suggest the TMC identify a mix of TMC staff to work through the Guide. Jointly agree on a schedule for completing the Guide process.
- Phone conversation #2: Check on their status and answer any questions relating to the Guide and their selected weather integration strategies. Review the weather integration plan outline and offer guidance to help assure that the plan fits their needs and corresponding strategies.
- Phone conversation #3: Check on their status and answer any questions relating to the development of their draft weather integration plan.
- Phone conversation #4: Receive their final weather integration plan and discuss other input and feedback to improve the Guide and the self-evaluation and planning process.

Specific deployment plans were prepared and focused on each Tier 2 TMC that defined the activities to be conducted as part of the project tasks. Table 6 and Table 7 provide the deployment plans. Slight schedule alterations were made as necessary to ensure a smooth project implementation.

The next section provides the results of the work each TMC accomplished through the development and implementation of their deployment plans.

Table 6. Weather Information Integration Deployment Plan Overview: Redding, California

Tier 2 TMC	Redding, California Caltrans District 2 TMC
General Description: This Caltrans District-wide TMC located in Redding, California (north central) manages all the California state highways and Interstates in a large seven-county area. The area experiences heavy rain, flooding, snow at the higher elevations, fires, and high winds. They currently exhibit a low level of weather integration and are very interested in enhancing their capabilities in this area. They represent a large geographic rural area with numerous state highways and Interstates that experience a variety of severe weather conditions that affect the highways and the safety of the traveling public.	
Primary Contact:	**Phone:** 530-225-3245
Clint Burkenpas, District Traffic	**Email:** clint_burkenpas@dot.ca.gov
Others Involved: None at time plan developed.	

Planned Activities and Tentative Schedule	
Activities	**Preliminary Dates**
Phone conference 1: Kickoff and introduction discussion	4/16/09
TMC builds internal team	4/23/09
TMC completes self-evaluation and identifies Wx integration strategies	5/29/09
Phone conference 2: Check status and answer questions	6/9/09
TMC team finalizes strategies and prepares draft Integration Plan	7/29/09
Phone conference 3: Check status and answer questions	7/31/09
TMC team finalizes Integration Plan	8/14/09
Phone conference 4: Receive final Integration Plan and other feedback	8/26/09

Project Approach/Weather Integration Opportunities:

The Caltrans District 2 TMC will be introduced to the Guide and provided instructions on its use. They will conduct the self-evaluation process and be asked to develop an Integration Plan with only a minimum of involvement and assistance from the consultant. Four phone conferences will be conducted to check on their status and answer any questions they may have. Their weather integration opportunities include strategies that would provide better road weather forecasting of storm intensity (amount of rain or snow) and more specific locations (road weather information displayed on map).

The Consultant's Planned Involvement:

The consultant team involvement with the Caltrans District 2 TMC will be kept to a minimal level to provide general assistance and check-in phone conferences to track their progress with the self-evaluation, weather integration strategies and preparation of an Integration Plan.

Table 7. Weather Information Integration Deployment Plan Overview: Cheyenne, Wyoming

Tier 2 TMC	**Wyoming Statewide TMC**
General Description: The state of Wyoming has one TMC in Cheyenne that manages the Interstates and all state highways that provide the majority of the transportation network throughout this extremely rural state. They primarily experience heavy snow, high winds, and blowing/drifting snow throughout the state. Interstate 80 is a major commercial goods transport corridor that traverses the lower portion of the state. The TMC exists primarily to address severe weather conditions that frequently close important Interstates and state highways throughout the state during the winter months. They currently demonstrate a medium level of weather integration and are very interested in enhancing their weather integration capabilities. They represent a rural statewide TMC with severe weather conditions that significantly impact travel within the state.	
Primary Contact: Vince Garcia, ITS Program Manager	**Phone:** 307-214-0235 (cell) **Email:** vince.garcia@dot.state.wy.us
Others Involved: Kevin Cox, ITS-Systems Engineer; 307-777-4620; kevin.cox@dot.state.wy.us.	
Planned Activities and Tentative Schedule	
Activities	**Preliminary Dates**
Phone conference 1: Kickoff and introduction discussion	4/22/09
TMC builds internal team	4/23/09
TMC completes self-evaluation and identifies Wx integration strategies	5/29/09
Phone conference 2: Check status and answer questions	6/9/09
TMC team finalizes strategies and prepares draft Integration Plan	7/29/09
Phone conference 3: Check status and answer questions	7/31/09
TMC team finalizes Integration Plan	8/14/09
Phone conference 4: Receive final Integration Plan and other feedback	8/26/09
Project Approach/Weather Integration Opportunities: The Wyoming Statewide TMC will be introduced to the Guide and provided instructions on its use. They will conduct the self-evaluation process and be asked to develop an Integration Plan with only a minimum of involvement and assistance from the consultant. Four phone conferences will be conducted to check on their status and answer any questions they may have. Their weather integration opportunities include strategies that would provide the means to automatically control traffic management devices on their Interstates and major state highways (such as variable speed signs).	
The Consultant's Planned Involvement: The consultant team involvement with the Wyoming Statewide TMC will be kept to a minimal level to provide general assistance and check-in phone conferences to track their progress with the self-evaluation, weather integration strategies and preparation of an Integration Plan.	

3.0 Identification of Weather Information Integration Strategies and Plan Preparation at TMCs

This section describes the support provided each of the five TMCs, identifies weather information integration strategies for each TMC, and summarizes the integration plans produced by the TMCs (complete plans are provided in the appendices).

3.1 TMC Self-Evaluation and Development of Weather Information Integration Plans

The consultant team provided varying levels of support for the five TMCs. With assistance provided through periodic conference calls and several site visits, the Tier 1 TMCs all completed the self-evaluation process and developed a weather integration plan. These plans are included in the appendices. The Tier 2 TMCs completed the self-evaluation process with significantly less support and identified weather integration strategies. One of the Tier 2 sites was able to develop an integration plan. The primary reason the other site did not develop a plan was the other demands placed on the TMC that were of higher priority.

Each TMC brought together a group of individuals representing specific functions within the TMC or an outside agency related to the process, to work through the self-evaluation process. These groups understood the range of TMC weather needs, the missions of the TMCs, and the value of establishing close working relationships with stakeholders outside the TMC. The varying perspectives from each member of these working groups were immensely valuable. New working relationships were established and weather information was shared.

The weather integration self-evaluation and planning process is illustrated in Figure 2. The process is divided into three major segments, each with a specific objective as shown in the figure. Segment 1, Self-Evaluation, concludes with a TMC identifying and prioritizing a set of weather related needs. Segment 2, Guidance for Weather Integration, maps the needs to a set of weather integration strategies and provides information about each strategy so that the TMC can select which ones best fit their most urgent needs and their operational constraints. Following selection of the strategies, the TMC is then encouraged to prepare an integration plan that describes in more detail what tasks they will perform to implement the selected strategies. All of the possible weather integration strategies by category and level are described in Table 8.

Twenty-three specific weather information/integration needs in five different categories are reviewed by the TMC as they progress through the self-evaluation process. Each TMC identifies the needs that are specific to its operation and approach to using weather information. Table 9 displays the list of needs including those each TMC in this study identified as its top priority. The table lists the Tier 1 TMCs' needs that they selected to emphasize in the process of identifying their weather integration strategies; other secondary needs were also noted by these TMCs as they went through the self-evaluation process.

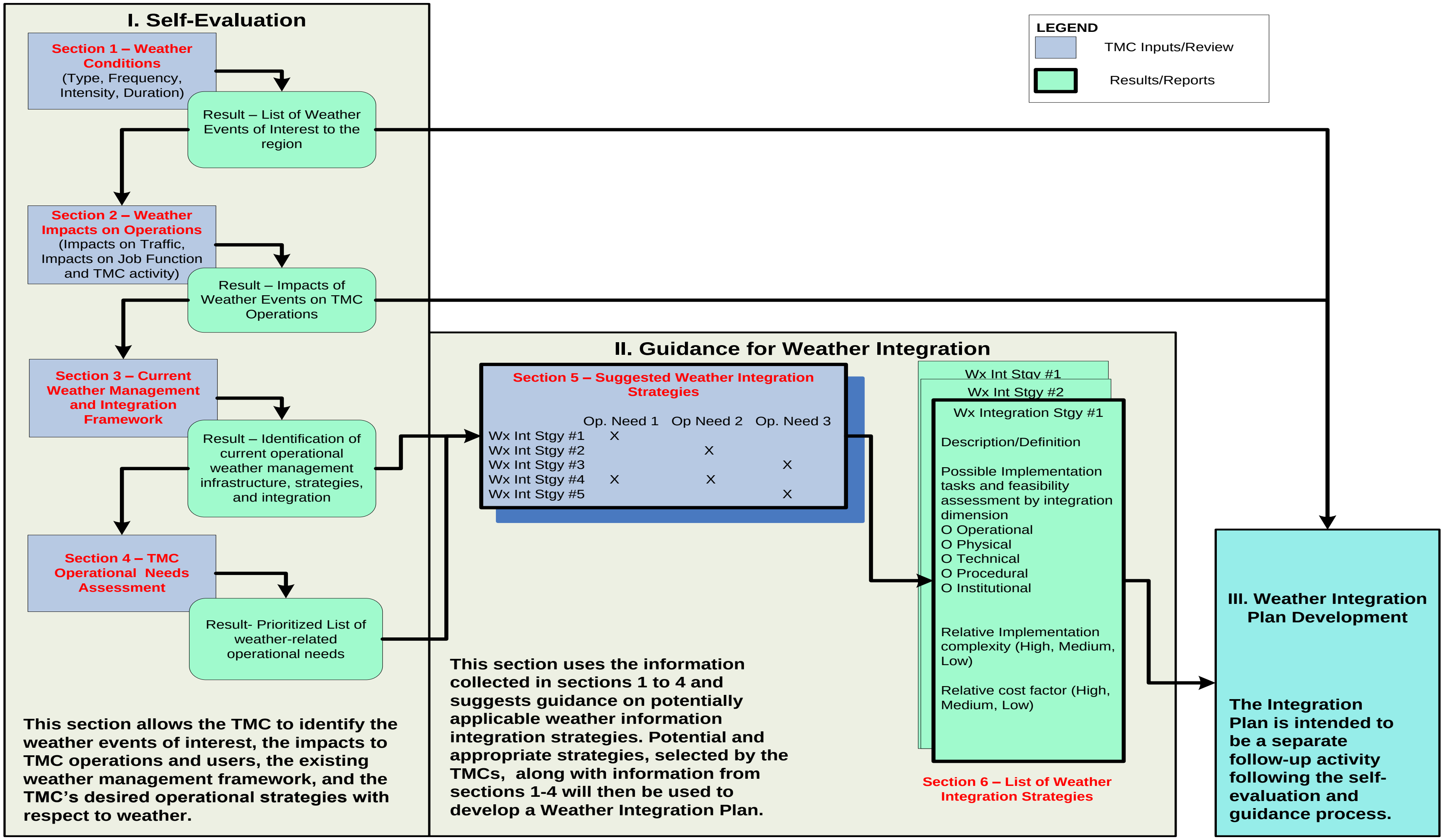


Figure 2. Weather Integration Self-Evaluation and Planning Process

Table 8. Weather Integration Strategies by Category and Level

Items of Integration	Strategies				
	Level 1	Level 2	Level 3	Level 4	Level 5
Use of Internal Weather Information Resources	Camera imagery	Radar, satellite, Automated Surface Observing System (ASOS) and Automated Weather Observing System (AWOS) data, and general zone-type forecast information	Level 2 data plus data from Road Weather Information Systems (RWIS) and related networks	Level 3 data plus data from Automatic Vehicle Locations/Mobile Data Computers (AVL/MDC) sources and internal radio communications	Level 4 data with addition of analyzed fields and transformed data parameters (frost index, wind chill, est. snow, ice, water depth)
Use of External Weather Information Sources	General weather information, forecasts, and interpretation provided through media as irregular service (radio and TV weather)	Internet provided, public access general forecasts, weather radar or satellite image or weather-specific broadcast channel	Field observers or probes providing scheduled weather / driving condition information from entire route system	Contractor provided surface transportation weather forecasts targeted at the operational needs of the TMC agencies	Direct connection between private weather information service providers and traffic management software
Availability of Weather Information	Cable channel or subscription weather information vendor providing general weather information	Internet provided weather radar or satellite image on video wall	Field observers or Environmental Sensor Station (ESS) network providing scheduled road or driving condition reports	Vendor provided daily surface transportation weather forecasts and observed weather conditions including Level 3	Meteorologist, located within TMC, forecasting and interpreting weather
Frequency of Weather Forecasts	Receive information of weather forecasts on a request basis	Receive weather forecast once daily.	Receive periodic forecasts several times a day	Receive hourly updates of weather forecasts several times a day	Receive continuous updates of weather forecasts in real-time

Items of Integration	Strategies				
	Level 1	Level 2	Level 3	Level 4	Level 5
Frequency of Weather/Road Weather Observations	Receive information of weather conditions on a request basis	Receive weather observations once hourly	Level 2 plus receive weather/road weather observations when predefined thresholds have been exceeded	Receive weather/road weather observations every ten minutes and when predefined thresholds have been exceeded	Receive weather/road weather observations continuously with data above predefined thresholds highlighted
Weather Information Coordination	Intra-TMC committee tasked with weather information coordination	Identified TMC or maintenance staff member tasked with coordinating weather information at TMC	Dedicated weather operations supervisor	Meteorology staff located within the TMC forecasting and interpreting weather information	Co-location of the Emergency Operations Center/Office of Emergency Management (EOC/OEM)
Extent of Coverage	Sparse Set of Isolated Locations	Network of Scattered Locations	Corridor-level	Multiple-corridor/sub-regional	Regional/Statewide
Interaction with Meteorologists and Climatologists	Focus group or informal gatherings of local professionals from the transportation management and weather communities	Develop check list of routine weather awareness activities	Periodic staff meeting that includes a meteorologist to discuss weather information needs and responses	With a meteorologist present conduct post-event debriefing / regular assessment to fine-tune responses	Daily personal briefings and integrated interruptions by meteorology staff within the TMC
Alert Notification	Monitor media outlets, Internet page, or data stream for critical events	Telephone call list	Manual email/paging system	Automated TMC road weather system-generated notifications (e.g., Email or page from Road Weather Information System or Flood Early Warning System)	Automatic notification through Center-to-Center communications

Items of Integration	Strategies				
	Level 1	Level 2	Level 3	Level 4	Level 5
Decision Support	Ad-hoc implementation of weather management strategies	Use quick-reference flip cards on operator's workstation to implement predefined response	Response scenarios through software supply potential solutions with projected outcomes based on weather / traffic modeling	Automated condition recognition and advisory or control strategy presented to operator for acceptance into ATMS	Automated condition recognition and advisory or control strategy implemented without operator intervention
Weather/Road Weather Data Acquisition	Media Reports	Internet and/or Satellite Data Sources	Across agency intranet and dedicated phone acquisition	Dedicated communications link to state, federal, private data sources	Dedicated communications link to state, federal, private data sources including vehicle-derived weather data

Table 9. Needs that Determined Weather Integration Strategies at Tier 1 TMCs

Weather Integration Needs	Colorado Springs TMC	Louisiana TMCs	Kansas City Scout TMC
Weather Integration Gathering and Processing			
Better short-term forecasts of arrival time, duration, and intensity of specific weather cells (events) at specific locations			
Better prediction of impact of weather events including assessment of reductions in capacity	✓		
Better real-time information on road conditions during weather events	✓	✓	✓
Improve the coverage and granularity of weather information in the region		✓	
Assistance in interpreting weather information and how best to adjust operations in light of that information	✓	✓	✓
Institutional Coordination			
Develop and implement clear, written policies and procedures for handling weather events		✓	✓
Improve coordination within the TMC operations			
More coordinated responses and information sharing with adjacent jurisdictions/regions	✓		
Improve coordination with local public safety and emergency agencies	✓		
More opportunities and mechanisms for communications and exchange with others in the weather community and those with experience dealing with weather events			
Advisory Operations			
Disseminate weather information to a larger set of stakeholders and users in the region (including transit and other modes)			✓
Improve message content (for DMS, 511, HAR, websites etc)	✓	✓	
Improve targeting of weather messages (site-specific, user group specific) to more effectively convey road weather information		✓	
Provide better pre-trip weather information to aid travelers in their decision making	✓		
Provide better en-route weather information to aid travelers in their decision making			✓
Control Operations			
Improve management of emergency routing and evacuation for large-scale weather events			
Improve traffic diversion and alternate routing capabilities			
Improve safety at intersections during weather events	✓		
Improve traffic signal timing during weather events to facilitate traffic movement	✓		

Weather Integration Needs	Colorado Springs TMC	Louisiana TMCs	Kansas City Scout TMC
Treatment Operations			
Assist maintenance in better determining the optimal treatment materials, application rates, and timing of treatments.			
Improve the timeliness of weather management response including deployment of field personnel and equipment			✓
Reduce the time required to restore pre-event level of service operations after a weather event			
Reduce costs of roadway treatment options			

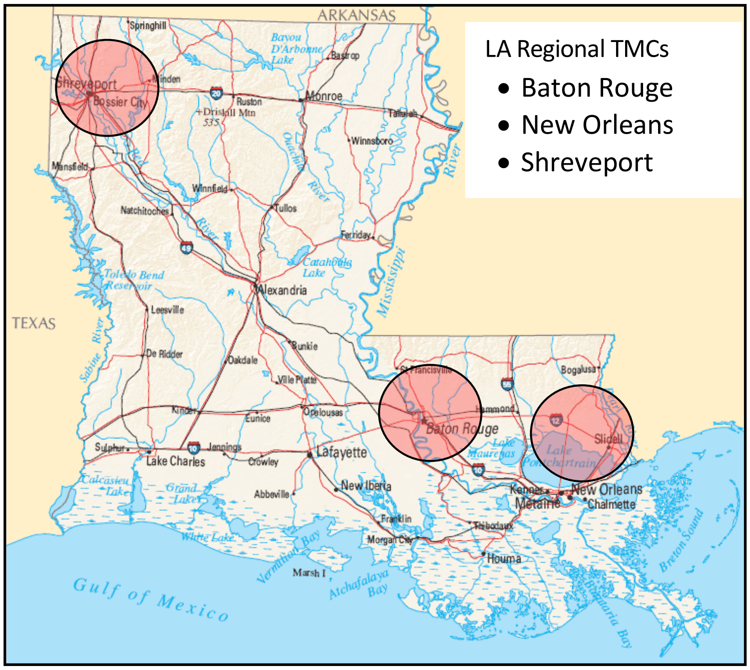
The subsections that follow summarize the efforts each TMC undertook to conduct a self-evaluation and develop an integration plan. The Tier 1 TMCs are described in terms of their operational characteristics, weather integration strategies (that correspond to their needs shown in Table 9), and the implementation plans that were created to guide their integration activities in the coming months and years. The Tier 2 TMCs are described by their efforts to conduct the self-evaluation and develop plans on their own.

3.2 Louisiana Statewide and Regional TMCs

3.2.1 Operational Characteristics

The regional and statewide Louisiana TMC operations staff work closely with one another to monitor and manage the operations of all interstate highways throughout the state. The TMCs operate Closed Circuit Television (CCTV) cameras, Dynamic Message Signs (DMS), Vehicle Detection (VD) devices, and the state's 511/Condition Acquisition and Reporting System (CARS) traveler information system. The TMC Operations Staff also dispatch the Motor Assistance Patrol (MAP) vans, send notification emails to key personnel, and use Twitter to alert motorists of hazardous road conditions. TMC locations are shown in Figure 3.

Louisiana experiences a wide variety of weather patterns across the state that impact road safety and operations. Heavy rain events cause flooding of roadways, heavy fog impairs drivers' visibility, tropical weather activity brings strong winds and heavy rains, and icy storms cause slippery roads. By integrating weather information into TMC operations, staff can inform drivers of hazardous weather conditions on the roads and aid in the reduction of weather-related vehicular accidents.



Source: Map provided by Louisiana TMC

Figure 3. Louisiana Regional TMCs

The Statewide TMC is located in Baton Rouge and oversees all field equipment and operations of the regional TMCs along with field equipment located in areas not covered by the regional TMCs. The Statewide TMC handles all regional based incidents and construction projects. It operates 24/7 and provides after-hour coverage for the regional TMCs.

The Shreveport TMC handles most of the northwest Louisiana area, including Shreveport and Bossier City and the surrounding areas. The interstates located within this area are I-20, I-220, and I-49.

The Baton Rouge TMC covers East Baton Rouge Parish and surrounding areas including Denham Springs, Port Allen, and Prairieville. Several major interstates and junctions are located within the Baton Rouge area I-10, I-12 and I-110.

The New Orleans TMC covers the greater New Orleans area, Kenner, Laplace, and the Northshore. I-10 and I-610 are within the New Orleans area, and I-12 runs through Hammond and Covington on the Northshore.

All incidents or construction in these areas are handled by the regional TMC. Each TMC can assist in any incident by activating DMS, notifying key personnel, dispatching MAP and entering the incident into the 511/CARS system. The TMCs work cohesively to assure all incidents, construction and other projects are proficiently handled.

3.2.2 Weather Information Integration Strategies

The TMC operations staff was able to determine the levels of integration under which each TMC was operating and what intermediate levels needed to be achieved. Based on the needs selected, the target levels of integration were determined by the Guide. Intermediate levels were chosen to provide smaller steps to achieve the target level. Once the selected intermediate steps have been reached, the TMC operations staff will reassess how to approach the next level of integration. This process is repeated until the target level is achieved. Table 10 summarizes the current level of integration, selected intermediate level, and target level defined by the Guide.

Table 10. Current, Intermediate and Target Levels of Weather Integration for the Louisiana TMCs

Items of Integration	Strategies		
	Current Level	Intermediate Level	Target Level
Use of Internal Weather Information Resources	2	3	4
Use of External Weather Information System	2	3	4
Availability of Weather Information	2	3	4
Frequency of Weather Forecasts	0	2	4
Frequency of Weather/Road Weather Observations	0	2	4
Weather Information Coordination	0	2	4
Extent of Coverage	0	2	5
Interaction with Meteorologists and Climatologists	0	2	3
Alert Notification	1	1	4
Decision Support	1	2	3
Weather/Road Weather Data Acquisition	2	2	4

3.2.3 Implementation Plan

The self-evaluation and planning guide lists 11 separate integration strategies that pertain to different areas of weather integration in TMC operations. After reviewing all the strategies it was decided that many of these strategies could be implemented by utilizing the same resources; therefore, the TMC operations staff decided to combine these strategies and organize them in the order in which they were expected to occur. With the integration plan completed, weather integration would be implemented at each TMC during the next two years.

Several activities were planned to be initiated by the TMC operations staff during the implementation process. Most would begin with a written Memorandum of Understanding (MOU) and changes to policies and procedures. With these changes, the roles of the TMC Operations Staff when responding to weather-related events would change, becoming more proactive in response to road/weather information. Activities that were planned to be started at the TMCs during the initial integration of weather information included writing the policies and procedures to integrate weather and traffic information, coordinating with MAP operators and State Police on weather/road observations, and reporting.

Several projects were being implemented by the Department of Transportation and Development (DOTD) that included placing CCTV cameras and DMS in the New Orleans and Lafayette areas. With the installation of new equipment to inform travelers and to be able to monitor incidents and traffic, the TMC Operations Staff anticipated they would be better-equipped to handle weather-related events proactively. The first two years of the plan would be devoted to developing plans and policies and acquiring data in order to provide the necessary resources to manage weather events.

In the first 6 months the TMC Operations Staff planned to identify all weather information sources such as MAP, State Police, and Louisiana State University (LSU). These sources were discussed in the first through fifth and eighth integration strategies. The flow of information would be discussed, so the information could be received and properly used. The goals and plans of the TMCs would then be established, making all participating groups aware of them. Also within this timeframe a weather coordinator would be appointed to write, implement, and direct this plan.

Concurrent with the first set of goals, in the next 12 months, the TMC operations staff planned to develop policies and procedures. These policies and procedures would be developed in order for the flow of information to be utilized properly and efficiently. In these policies and procedures, definitions of advisory thresholds would be defined for statewide consistency. Although agencies and equipment would be different among the TMCs, the standard operating procedures would be the same for each TMC. Also during this time, the pilot sites would be established, and DOTD would develop detailed road device deployment plans for the sites which were discussed earlier, such as the Atchafalaya Bridge, Bonne Carre Bridge, and Red River Bridge.

Within the next 18 months, the pilot sites would be tested with RWIS equipment. During this time the weather coordinator would collect data, and the policies and procedures would be followed in order to ensure that the potential pilot sites were operating correctly. These pilot sites were intended to help determine the usefulness of the equipment and resources.

Within the next two years, the TMC Operations Staff would update the integration plan in order to identify the next steps in the weather integration process. Since the TMC operations staff chose an intermediate level, with the ultimate goal being the target level the Guide originally provided, the Guide would be revisited each year until the TMC operations staff and DOTD had made all the desired improvements for weather integration.

Table 11 lists the integration strategies previously discussed, implementation timeframe, and the sequence in which they should be reached.

Table 11. Integration Strategy Timeframes and Sequencing

Items of Integration	Implementation Timeframe	Implementation Sequencing
Use of Internal Weather Information Resources	1 year	1
Use of External Weather Information System	2 years	2
Availability of Weather Information	2 years	2
Frequency of Weather Forecasts	1 year	1
Frequency of Weather/Road Weather Observations	1 year	1
Weather Information Coordination	2 years	3
Extent of Coverage	5-10 years	4
Interaction with Meteorologists and Climatologists	2 years	1
Alert Notification	2 years	3
Decision Support	2-3 years	3

3.3 Kansas City Scout TMC

3.3.1 Operational Characteristics

Kansas City Scout (KC Scout) is a comprehensive traffic congestion management and traveler information system conceived, designed, and operated jointly by two Departments of Transportation, a fact that is unique throughout the country. In September of 2001, the Missouri Department of Transportation (MoDOT) and the Kansas Department of Transportation (KDOT) jointly announced their bi-state initiative to address traffic impacts on over 100 miles of contiguous freeways intersecting both sides of the state line throughout the greater metropolitan Kansas City area.

KC Scout's goal has been to offer area drivers the latest in technology and communications to help make their daily commute safer, faster and more manageable. Construction was already underway for MoDOT's new District 4 Headquarters in Lee's Summit, MO and it was decided that a state-of-the-art TMC could be housed within the new building. The Federal Highway Administration funded 90% of the initial $35.5 million start up costs, with the remaining funding for the project shared between both state DOTs.

The KC Scout TMC was completed and opened in late 2003 and has become recognized as an innovative leader in ITS deployment with an integrated system of 138 closed-circuit television cameras (CCTVs), 38 dynamic message signs (DMS), 277 vehicle detector stations (VDS), a highway advisory radio (HAR) system and a dynamic web site offering users the capability of designing their own customized alert messaging profiles.

The Kansas City Scout TMC began limited operations in January 2004 with 75 miles of coverage on portions of I-70, I-435, I-35 and several state highways in both Missouri and Kansas. The official public launch was held during a ceremony on September 27, 2004 attended by city, state and federal officials along with media and emergency service providers.

Kansas City Scout encompasses the jurisdictional boundaries of Cass, Clay and Jackson counties in Missouri and Johnson and Wyandotte counties in Kansas. Population for those respective counties is as follows (Table 12):

Table 12. Population Size for Selected Kansas and Missouri Counties

County	State	Population
Cass	MO	95,781
Clay	MO	206,957
Jackson	MO	664,078
Johnson	KS	516,731
Wyandotte	KS	155,509

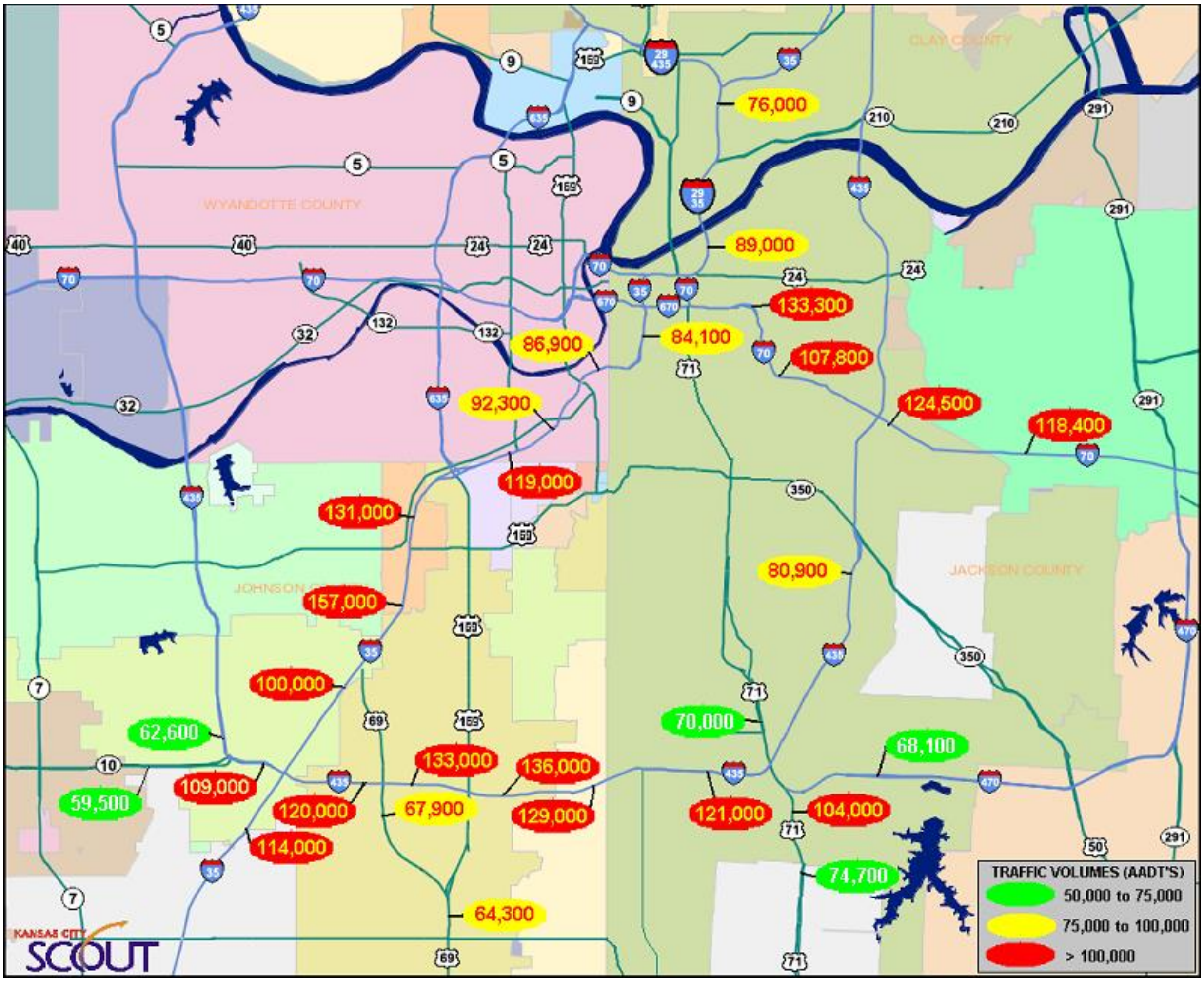
KC Scout has maintained 24/7 operational hours since July 2005. Staffing levels vary between three shifts (6A-2P; 2P-10P and 10P-6A). Peak hours are staffed with a minimum of two operators and one floor supervisor. Due to the collocation of MoDOT's customer service department within the TMC, information relayed to the public is also readily available to Scout operations.

Additionally, KC Scout is supported on both sides of the state line by motorist assist operations. They provide on-the-road assistance to motorists needing help with flat tires, low fuel, etc. and actively patrol the interstates looking for road hazards, tagging abandoned vehicles, and assisting with traffic control on incidents where lane restrictions have occurred due to stalls, accidents, traffic stops or weather impacts, such as flooding, ice covered bridges and overpasses, and debris from storm related events.

KC Scout's coverage area is at the very crossroads of the nation's network of interstate highways with 105 miles of monitored, contiguous roadways carrying high volumes of commercial, commuter and non-local motorists. Therefore, any weather conditions that affect the highways become of critical importance in terms of congestion, accident response, emissions, and driver impatience.

During winter storm events, MoDOT's traffic department staffs a separate workstation within the TMC, solely for the purpose of monitoring road conditions and reporting on the snowplow activity within its local coverage area. This is of great assistance to KC Scout operations because the information can be used to post DMS messages in advance of the plows, helping to keep those lanes clear of through traffic that would otherwise impede plowing activity.

Figure 4 shows Average Annual Daily Traffic (AADT) for the freeway facilities on the Scout system.



Source: Map provided by KC Scout

Figure 4. AADT Data as of September 2009

The I-70 interstate reaches across Missouri from the Illinois state line to the Kansas state line. It is the nation's fifth largest east-west corridor, passing through 10 states from Maryland to Utah.

3.3.2 Weather Information Integration Strategies

KC Scout's work with the Guide yielded a set of target strategies that identified the delta between where the TMC was and where they wanted to be in terms of weather information integration. Those results are shown in Table 13 below.

Table 13. Summarized Levels of Chosen Integration Targets

Integration Item	Current Integration Level	Guide Recommended Integration Level	Chosen Weather Integration Level	Rationale/Comments
Use of Internal Weather Information Resources	2	3	3	RWIS to be deployed in Missouri in 2010
Use of External Weather Information Resources	2	4	3 & 4	Utilizing field and contractor provided data
Availability of Weather Information	2	4	3 & 4	Utilizing field and vendor provided daily surface info
Frequency of Weather Forecasts	4	4	4	Hourly updates several times a day is reasonable
Frequency of Weather/Road Weather Observations	3	3	3	Observations hourly or whenever pre-determined thresholds are exceeded
Weather Information Coordination	0	3	1 & 2	Project team will remain active with project coordinator from TMC
Extent of Coverage	0	5	1 & 2 & 3	Coverage up to corridor level
Interaction with Meteorologists	0	3	1 & 2 & 3	Informal meetings, informational checklists and scheduled sessions with Meteorologist from NWS
Alert Notification	1	4	4	RWIS generated data received electronically
Decision Support	1	3	3	Utilization of 'what if' scenarios for training and projected outcomes
Weather/Road Weather Data Acquisition	2	3	3	Intra-agency and dedicated hotline for notification and advisories

3.3.3 Implementation Plan

Implementation planning is intended to address the steps necessary to achieve their high need objectives. The six target strategies included:

- Disseminate weather information to a larger set of stakeholders and users in the region (including transit and other modes)
- Provide better en-route information on weather conditions to aid travelers in their decision-making

- Develop and implement clear, written policies and procedures for handling weather events
- Improve the timeliness of weather management response including deployment of field personnel and equipment
- Provide assistance in interpreting weather information and how best to adjust operations in light of that information
- Create better real-time information on road conditions during weather events.

Many of the selected strategies involved tasks that were moderate in terms of their complexity and cost to implement. These involved readily available data link connections from external sources and internally developed policies and procedures. In cases where equipment had to be purchased, installed and maintained (i.e., RWIS or Automated Vehicle Location (AVL)/Mobile Data Computer (MDC)) the costs were justified in terms of the added level of service Scout would be enabled to provide.

Scout's TransSuite™ ATMS Software. Providing the core platform for Scout's TMC operation is its state-of-the-art ATMS. Within this framework, CCTVs, DMS and VDS are controlled and monitored.

Prior to September 2009, Scout used a UNIX-based system that furnished little support for enhancement development, report generation or operator efficiency. Many manual workarounds were developed by Scout staff that were time consuming to create and maintain but provided the level of utility desired to create and monitor incidents, track and trend activity, and provide management reporting capabilities. Inbound weather information consisted of daily MoDOT radio broadcasts of WeatherOrNot™ furnished forecasts or Internet-based weather media channels monitored on individual desktops. Scout operators became adept at identifying changing weather conditions while constantly monitoring CCTV cameras spanning 100-plus miles of interstate in the metro KC area. Weather information was more than just a component of the ATMS architecture platform.

On September 1, 2009, Scout successfully deployed TransSuite™ ATMS software. This represented the first major update to Scout's core ATMS platform since the TMC began formal operation in January of 2004. The effort resulted from two years of detailed planning, needs assessment and testing, largely driven by what had been lacking in the legacy system, i.e., scalability, adaptability and ease-of-use. The Windows/SQL-based TransCore™ product deployment was nearly seamless and has streamlined all the processes associated with creating and monitoring traffic incidents, activating and updating DMS message boards and linking all pertinent incident information into easily accessible databases and reporting tools. The user-interface utilizes a series of "layers" that visually represent infrastructure (CCTVs, DMS, VDS), traffic incidents, scheduled events (roadwork) and special events (heavy traffic stadium/concert events).

With this added flexibility, Scout will soon be able to integrate weather information into the user-interface as another "layer" utilizing the lat/long data link connectivity available from external weather information sources, e.g. NOAA, National Weather Service's (NWS) National Digital Forecast Database (NDFD), and Meridian-511 providers. As an example, when a weather condition exists that meets pre-selected alert threshold criteria, a "layer" will "activate" on the operator's ATMS desktop map application, signaling creation of a weather event type "incident" with applicable DMS messaging and outputs to Scout's website and subscriber-configured WebAlert applications. The quickness of being able to notify motorists of a rapidly developing severe weather condition will aid in their decision-making and hopefully reduce severe weather related crashes on the interstate. The next upgrade will accommodate this added weather data functionality. Training on the use of these new elements will require TMC staff development along with support system documentation, but the resources currently exist to complete these efforts.

Partnerships between Stakeholders. Partnerships between stakeholders are well established. Scout's Board of Directors has endorsed this project as a planning mechanism, but all proposed changes would first need to be reviewed and approved before any formal implementation can begin. This board meets every three months but opportunities exist to communicate with them as needed. The board reviewed the Implementation Plan at its meeting on March 25, 2010.

Summary of the Implementation Plan. Figure 5 identifies the specific tasks to be accomplished to achieve the Implementation Plan objectives identified at the beginning of this section. Also the figure illustrates the timeline of activities for each task. Table 14 identifies each task with key inputs and outputs, along with the key responsible KC Scout staff assigned. The information contained in Figure 5 and Table 14 will be used to guide the activities to successfully implement the weather integration tasks.

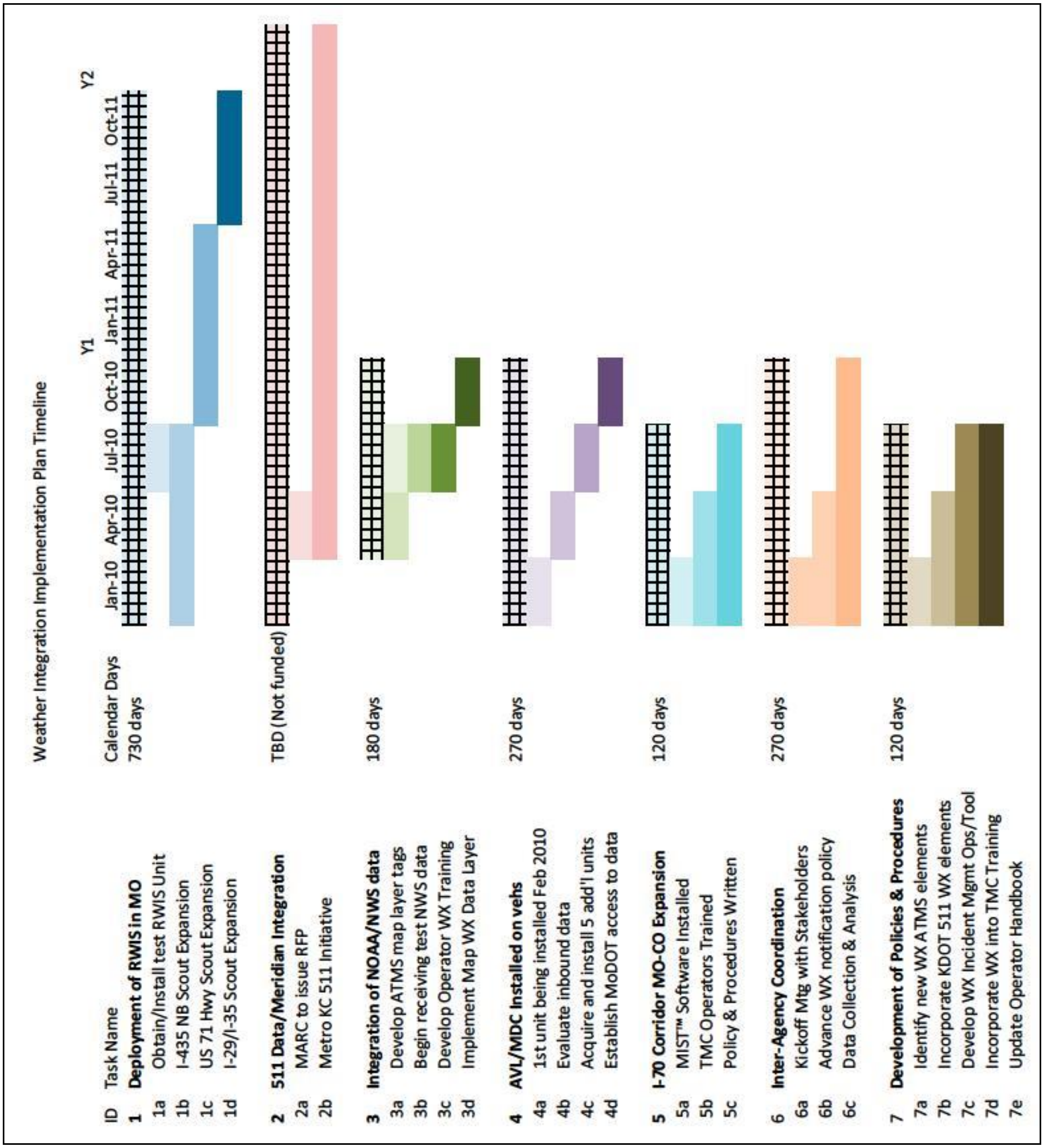


Figure 5. Implementation Timeline

Table 14. Identified Project Tasks for Implementation

ID	Task Name	Owner	Inputs	Outputs	Proposed Timeline	Current Status
1	RWIS Deployment (MO)	Jason Sims (KC Scout)	Contracts awarded Scout expansion -I-435 NB -US 71 Hwy -I-29/I-35	-Realtime Wx data -Improved maint. response time -Accident reduction analysis -Cost/benefit analysis	January 2010 Start (as part of current construction activity on three (3) Scout expansion projects	Delayed to spring 2011, due to need to get power to selected locations
2	Meridian Data Integration from 511 (KS/MO)	Barb Blue (KDOT)	Existing KDOT 511 data -36 sources -24x7 -Road & segment specific -Available *Clarus* data	-Link to Scout website/ATMS -Map layer integration -Threshold targets ID'd	KDOT 511 data available now KC Metro 511 On hold pending funding	KDOT 511 in use and mobile app now offered/ KC Metro 511 still on hold
3	Integration of NOAA datasets enabling alert notification of impending adverse weather conditions	Don Spencer (KC Scout)	-GIS shape files -polygon links	-ATMS Map Layer -Scout specific WX alerts output via Web -Group list notification	Spring 2010	Expect to implement summer 2011 and available by fall 2011
4	AVL/MDC installed on MA/ER vehicles	Jason Sims (KC Scout)	-Road condition data elements -Displayed on TMC operator workstations	-Real-time Wx information -Ability to provide advance info to maintenance personnel	Single evaluation unit to be installed March of 2010 Additional deployments Summer 2010	Deployed in 1/3rd of fleet, with balance pending funding
5	I-70 Corridor Mgmt (from MO to CO)	Jason Sims (KC Scout)	-KDOT Maint & Ops notification of Wx events	-Activation of KDOT Wx messaging and CCTV monitoring	Spring 2010	MO cameras and DMS fully integrated into ATMS by summer 2011
6	Inter-Agency Coordination	Jason Sims (KC Scout)	KDOT, MoDOT, NDOR City of Omaha Topeka TMC	-Proactive Wx messaging -TMC POC specific emails	Summer 2010	On-going integration through ATMS
7	Development of Policies and Procedures Relative to Weather Integration	Nancy Powell (KC Scout)	-Integrated weather layer within ATMS software -Integrated KDOT 511 weather data elements (*Clarus*)	-Incorporate weather incident mgmt into standard operating procedures and training manuals	Summer 2010	On-going, Prelim report expected summer 2011

3.3.4 Post-Implementation Evaluation Planning

As KC Scout continues to deploy their weather integration strategies, they are developing a Post-Implementation Evaluation Plan. Their intent is to assess the ability of their ATMS with integrated weather information to help their operators initiate the actions necessary to proactively respond to forecast weather events through their ATMS, activate the appropriate DMS signage from a predetermined library of approved messages, and manage the event effectively. The expectation is that this system with its enhanced and integrated weather information will result in timelier messaging for the traveling public, along with more proactive internal sharing of weather information between operations and maintenance, and will result in improved highway performance and traveler safety. Figure 6 was used in a meeting with KC Scout to help guide the early planning to evaluate the performance of their ATMS with fully integrated weather information.

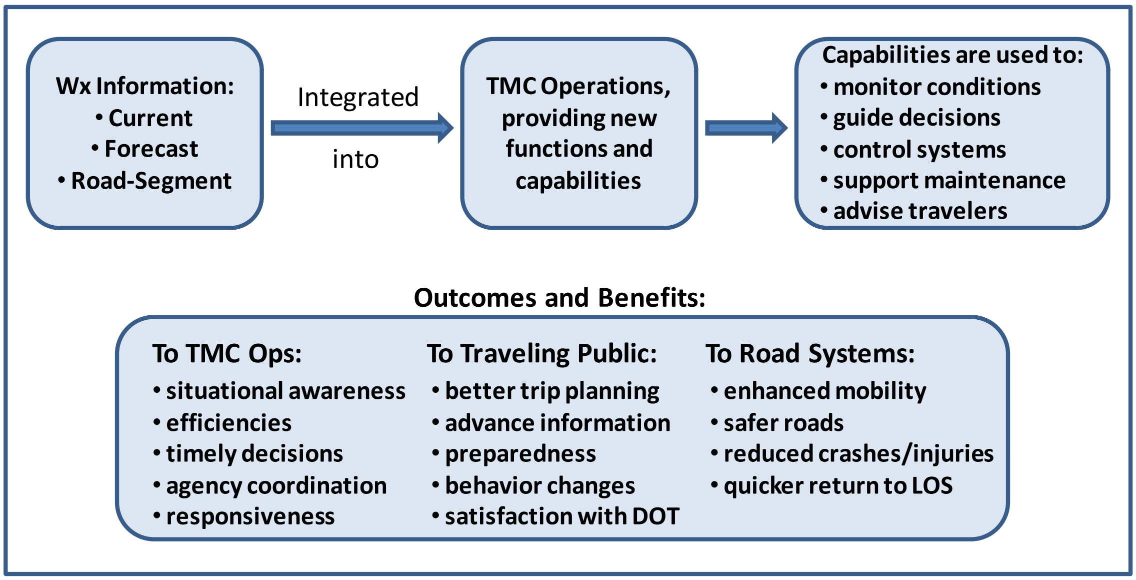


Figure 6. Pathway to Benefits from KC Scout's ATMS Integrated with Weather Information

Although the evaluation plan is not yet prepared, KC Scout is working on how to structure the evaluation. Elements that are under discussion and development at KC Scout include:

- The importance of assuring that the integrated ATMS system is fully functional, that operators have been trained in the use of any new components associated with the acquisition, integration, processing and dissemination of weather information, and enough time has elapsed that the use of the new system has become relatively routine for the operators; that is, with assurance that all or most of the "bugs" have been eliminated.
- The establishment of a fully-functional weather alert notification capability, with alert trigger thresholds that have been defined, implemented, and tested under real world conditions. Ideally, KC Scout will also have new procedures in place that guide the operators in the use of the system and their responses to weather alerts under varying conditions.

- Selection of the evaluation design that will be most appropriate to assessing the achievement of the desired outcomes, allowing KC Scout to attribute the measured outcomes to the effects of their weather integration program, and controlling for the effects of outside factors unrelated to weather integration (for example, other programs that have been developed that might also impact those outcomes, or variability in weather conditions that impact response times and other measured indicators).
- Identification of data requirements to support the evaluation, including sources of data, and specification of the time periods over which data will be needed, both for baseline conditions and post-deployment (if using a “before-after” evaluation design).
- Agreement on the measures of performance effectiveness that will be used in the evaluation to assess the benefits of weather information integration in their operations. Measures of effectiveness are being framed based on the following desired outcomes:
    - Timely posting and removal of weather event messaging to affect motorist behavior
    - Timely communication of weather information to internal and external parties
    - Improvements in maintenance performance due to more proactive weather alerting
    - Savings in areas of maintenance labor and costs associated with shortened time to achieve Level of Service (LOS) linked to the benefits of weather information received from the TMC
    - Reduction in the number of weather-related incidents at high accident locations
    - Improvement in response times to weather related incidents by DOT responders
    - Improvements in the level of customer satisfaction

KC Scout expects their new weather integration system to be operational in summer 2011. The evaluation plan should be complete at this time as well. The system will be tested through the remainder of this winter and through the summer months (strong thunder storms, etc.). The evaluation of the system will continue through April 2013 in order to capture data for two complete seasons.

3.4 Colorado Springs TMC

3.4.1 Operational Characteristics

The Colorado Springs Traffic Management Center (CSTMC) is very unique compared to the other centers in Colorado. It is a regional facility that covers the Pikes Peak region in El Paso County, CO. The center is run and operated by the City of Colorado Springs Traffic Engineering Division instead of by the Colorado Department of Transportation (CDOT). The CSTMC facility houses the Intelligent Transportation System (ITS) equipment and personnel. The ITS equipment includes the signal timing equipment and the computer systems to operate the traffic cameras and Variable Message Signs (VMS). Figure 7 shows a map of Colorado Springs.

Source: Map provided by Colorado Springs, Colorado TMC

Figure 7. Regional Map of Colorado Springs

All fiber communications are managed in the CSTMC. Some of the factual data for the center and the Pikes Peak region include:

- CSTMC incorporates the management and oversight of nearly 564 traffic signals in Colorado Springs.
- The center is open Monday through Friday from 6:30 am until 6 pm. During those hours the City of Colorado Springs is responsible for managing and controlling all the transportation management devices in the region, including the cameras and variables message signs on the I-25 Corridor. The after-hours control of the VMS reverts to the Colorado Statewide Transportation Management Center (CTMC). The after-hours traffic signal control is managed by the City of Colorado Springs through an emergency callout procedure. While the CSTMC is open from 6:30 am until 6 pm, the traffic signal technicians work between 7:30 am – 5:30 pm.
- The CSTMC has a total of 63 cameras and 47 VMS. There are 29 cameras and 31 VMS on I-25. The other cameras and VMS are on arterial roadways.
- There are 28 miles of coverage on I-25 in the Pikes Peak region with approximately 100,000 annual average daily traffic including 8% truck traffic.
- The population in the region is approximately 400,000.

- There are 1,300 roadway miles in Colorado Springs.
- The elevation in Colorado Springs ranges from 6,000 to around 7,000 feet. The highest elevation location on I-25 is on Monument Hill at approximately 7,300 feet.
- The City's Street Division is responsible for servicing over 7,423 lane miles of roadway, extending over a 196 square mile area. The services performed by the Street Division include pavement repairs and maintenance as well as snowfall removal.
- The average annual snowfall is 42 inches.

The CSTMC collects and distributes traffic information. The most common dissemination methods include VMS, Twitter and media releases. The types of traffic information include:

- Traffic Incidents (crashes, stalls, debris, etc.)
- Road work
- Major congestion
- Road weather conditions impacting driving
- Highway/street closures for emergency calls (fire, police, utilities)
- Power/traffic signal outages
- Fires (controlled burns, structure fires, vehicle fires and wildfires)
- Special events (parades, graduations, races, USAFA events, World Arena Events, etc.)
- Traffic campaigns in the State (DUI/seatbelt)
- Accident Alert Status (Cold reporting) for the Colorado Springs Police Department (CSPD) and Colorado State Patrol (CSP)
- Chain law restrictions for commercial vehicles for Monument Hill
- AMBER Alerts

The CSTMC is responsible for traffic signal timing and traffic signal coordination. The computerized Traffic Control System (TCS) allows city staff to continually evaluate and coordinate the City's traffic signals. The City Traffic Engineering staff studies and re-evaluates approximately 30 to 40 arterial streets each year for optimal coordination. The goal of traffic signal coordination is to progress the greatest number of vehicles through the system with the fewest stops and shortest amount of delay.

The traffic signal timing team is comprised of the City's Traffic Engineer and traffic signal technicians who specialize in the timing and coordination of the traffic signals. They gather data, evaluate, and study the major and minor arterial streets. They drive the arterial before and after the new coordination timing is applied to determine the effectiveness and efficiency of the new coordination.

Coordinated signals attempt to provide green lights for the major vehicle flow on a street. This requires that city staff gather data on the volume, speed, distance between signals, and the timing of individual intersections. When the data have been collected a study is done to determine the best timing and coordination of all intersections involved. This may require the timing of the intersections to be adjusted to facilitate the best flow of vehicles.

When the best coordination has been determined the team will implement the new timing plan. Studies are conducted to evaluate the efficiency and to make necessary adjustments. Coordination throughout the city is continually monitored and is reevaluated as needed.

Each arterial has special coordination needs and may require that various types of special timing plans be implemented to help the flow of traffic. To accommodate heavy travel demand periods, it may be necessary to have a long cycle length, and this may cause delays on the side streets. Some arterials may have a heavier flow in one direction. This movement may be favored, causing more stops in the less traveled direction. Some intersections may have lagging left turn movements. This means the left turn arrow comes on at the end of the green through light. There may also be planned stops on long arterials to help maintain the flow of vehicles.

Effective coordination greatly improves the flow of vehicles on the arterial by minimizing the interruption of traffic flow and reducing air pollutants. Other than placing a traffic signal in recall when video camera detection is iced over, the effects of weather on traffic flow have not been considered when establishing signal timing plans in the past. The weather integration plan will allow the staff to develop strategies for modifying signal timing plans in response to specific weather events.

A variety of weather in the region provides a significant challenge to motorists, highway maintenance and traffic signal crews. It also creates havoc with TMC equipment including the traffic signals detection cameras and the highway cameras. The weather systems effecting travel include winter snow storms, high winds, thunderstorms, street flooding and fog conditions.

The climate is very unique within the 194 square miles of the Colorado Springs city limits. While there is only a slight change in elevation in various parts of the city, the actual weather and road conditions can be drastically different at the same time in various locations in the city limits. The weather conditions in the spring and summer produce high winds, thunderstorms with flooding and lightning strikes and foggy conditions. The fall and winter produce high winds, snow storms with blowing snow, heavy snow and occasional extreme low temperatures and occasional foggy conditions.

Weather forecasting information is available from a variety of sources. The CSTMC operators have no set schedule to check the various sources of information.

3.4.2 Weather Information Integration Strategies

The CSTMC analyzed each integration strategy based on the current integration level and the Guide-recommended integration level based on the high priority needs identified in Table 9 above. The CSTMC personnel then determined a chosen weather integration level based on what was thought to be most feasible for the CSTMC. The integration strategies are listed in Table 15 below.

Table 15. Current, Recommended and Selected Weather Integration Strategies

Integration Item	Current Integration Level	Guide Recommended Integration Level	Chosen Weather Integration Level
Use of Internal Weather Information Resources	1	4	3
Use of External Weather Information Resources	2	4	3
Availability of Weather Information	2	4	4
Frequency of Weather Forecasts	1	4	3
Frequency of Weather/Road Weather Observation	1	4	3
Weather Information Coordination	None	4	2
Extent of Coverage	4	5	4
Interaction with Meteorologists	None	3	2
Alert Notification	1	4	3
Decision Support	1	3	2 & 3
Weather/Road Weather Data Acquisition	2	4	3

3.4.3 Implementation Plan

The plan for the CSTMC is to create operator-initiated signal timing plans based on weather observations and predictions. The process involves utilizing the City of Colorado Springs Street Department grid map and performing signal timing modification in each of the 16 grids. It is also a future goal to develop an automated modified signal timing plan in any or all of the 16 grids for weather related incidents. The automation can help reduce the need for after- hour staffing to manage the system.

The CSTMC has elected to conduct a pilot program and the timeline is outlined below. The plan is to utilize just a single grid from the 16 grids available. The project will include fine tuning and evaluating the signal timing plan in the grid selected. At the completion of the pilot project the signal timing plans can be implemented in all 16 grids.

The tasks are split into two categories. One is the weather integration related tasks and the other is traffic signal timing pilot project tasks. Each task and the proposed time frame for both start and completion are listed below in Table 16. Since this timeline was prepared, the demands on limited staff have caused the dates to be pushed out about a year to mid-2011. The pilot test is now expected to be initiated in the spring of 2011, and in anticipation of that, the TMC has begun training technical personnel, and they have installed and are testing several new cameras at selected intersections.

Table 16. Implementation Tasks and Time Frames

ID	Weather Integration Related Tasks	Start	Finish
A1	Collect baseline data in specified locations/grids	12/09	03/10
A2	Refine concept of operations and identify what weather information is needed	01/10	02/10
A3	Obtain training for weather coordinator	01/10	02/10
A4	Establish data triggers, notifications and actions	02/10	05/10
A5	Make adjustments to TMC displays to include cameras, radar and satellite	05/10	07/10
A6	Prepare standard operating procedures	08/10	09/10
A7	Alert notification to the motorist on weather conditions	On-going	
ID	**Traffic Signal Timing Pilot Project Related Tasks**	**Start**	**Finish**
B1	Identify performance measures and prepare plan	04/10	05/10
B2	Develop signal timing plans based on new weather information	05/10	08/10
B3	Provide training for signal technicians on new procedures	09/10	10/10
B4	Implement signal timing pilot project with automation	11/10	03/11
B5	Evaluate effectiveness	11/10	05/11

NOTE: The indicated start and finish dates have slipped approximately one year since this schedule was prepared.

3.5 Wyoming Statewide TMC in Cheyenne

The statewide TMC in Wyoming is one of the Tier 2 sites that received limited support for their weather information integration self-evaluation and planning process. They undertook the process on their own and prepared a weather integration plan that they are currently beginning to implement. Their operational characteristics, integration strategies, and implementation plan are discussed below.

3.5.1 Operational Characteristics

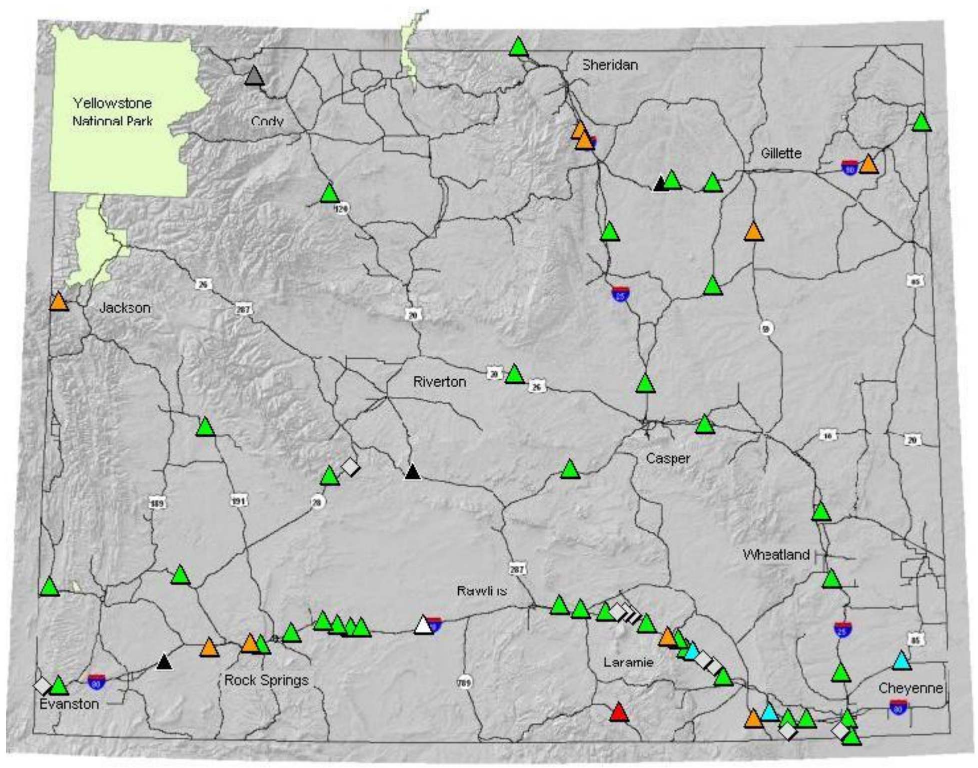
Wyoming DOT's (WYDOT) statewide TMC became operational in the fall of 2008. The TMC is housed in the basement of the Qwest building at 6101 Yellowstone Road in Cheyenne, Wyoming, approximately a mile north of the WYDOT headquarters complex. The TMC houses both the emerging ITS operations function and a new dispatch center for the Wyoming Highway Patrol.

While numerous states already have similar TMCs in operation to deal with urban traffic congestion, Wyoming's center is geared almost exclusively toward rural travel management and information needs that result from extreme weather conditions. Additionally, it is one of the few TMCs where communication services for DOT construction, traffic, and maintenance functions are co-located with law enforcement. The functions of the TMC have expanded over time, but the core functions can be grouped into the following four main areas:

- **Monitoring and control of roadside ITS devices** such as web cameras, RWIS, Variable Speed Limit (VSL) signs, DMS, HAR, flashing beacons, and road closure gates;

- **Serving as a law enforcement communications hub** for state and federal agencies by maintaining frequent contact with Highway Patrol troopers and other personnel via the State Law Enforcement Communications Systems (SALECS);
- **Managing communication with the traveling public** via the 511 Travel Information Service (telephone and internet components) and direct contact with media outlets, visitor centers, and truck stops;
- **Receiving and relaying road and weather reports** from volunteers participating in the Enhanced Citizen-Assisted Reporting (ECAR) program, as well as, dispatching WYDOT construction and maintenance crews throughout the state.

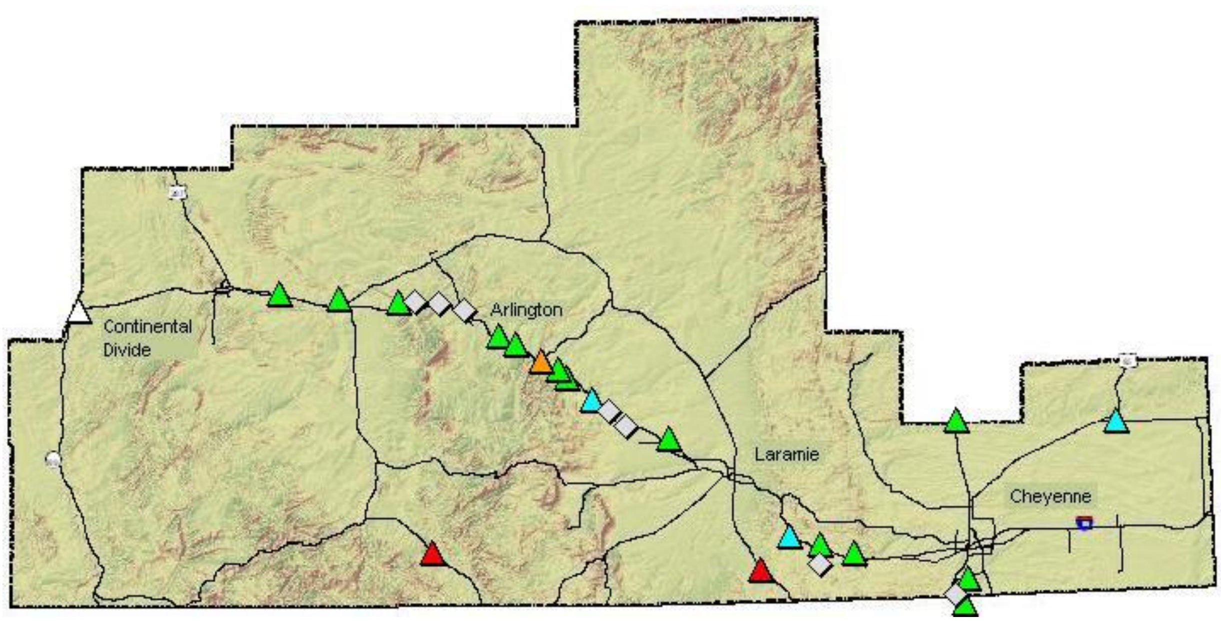
Currently, WYDOT has a network of 62 RWIS stations located throughout the state. They are managed by a central software system known as SCAN Web. Figure 8 and Figure 9 that follow are screen shots from that software, showing the statewide network, followed by a more detailed map of southeast Wyoming where WYDOT has deployed a greater density of RWIS for a 52-mile VSL corridor between Laramie and Rawlins.



Source: Screen shot from WYDOT's SCANweb system.

Figure 8. RWIS Locations Statewide

The VSL corridor is the first of its kind in Wyoming. It consists of a 52-mile stretch of Interstate 80 from Walcott Junction (20 miles east of Rawlins) to Quealy Dome Interchange (17 miles west of Laramie). In that 52-mile corridor, WYDOT now has 13 RWIS stations. This project represents the first corridor-level RWIS deployment in WYDOT's history.



Source: Screen shot from WYDOT's SCANweb system.

Figure 9. RWIS in Southeast Wyoming

3.5.2 Weather Information Integration Strategies

Table 17 provides a summary of WYDOT's integration strategies. The table shows WYDOT's current level for each integration item, the recommendation from the self-evaluation guide, the integration level selected by WYDOT for both the current (C) timeframe, and future (F) timeframe, and comments for each integration item.

Table 17. Summary of Integration Strategies

Integration Item	Current Integration Level	Guide Recommended Integration Level	Chosen Weather Integration Level (C/F)*	Rationale/Comments
1: Use of Internal Weather Information Resources	3	3	3/4	C=expand RWIS locations; F=outfit & receive data from plows & other vehicles
2: Use of External Weather Information Resources	4	4	4/4	Build integrated weather information tool to assist TMC operators
3: Availability of Weather Information	4	4	4/4	Availability meets current needs
4: Frequency of Weather Forecasts	4	4	4/4	Frequency meets current needs
5: Frequency of Weather/Road Weather Observations	2	3	3/3	Expand coverage and frequency of plow driver reports
6: Weather Information Coordination	None	3	3/3	Contracting with a part-time local meteorologist to perform weather information management tasks in TMC.
7: Extent of Coverage	2	4	4/5	C=Adding four more VSL corridors throughout the state; F=continued expansion of RWIS sites.
8: Interaction with Meteorologists	1	3	4/5	See item 6 above.
9: Alert Notification	4	4	4/4	Enhance alert notification in phases (use SCAN Sentry, expand METalert , build new alert system w/ new Wx info tool).
10: Decision Support	1	3	3/4	C=automated recommendations for VSL system; F=expand to DMS recommendations.
11: Weather and Road Weather Data Acquisition	4	4	4/5	C=continue current acquisition; F=automated data collection from DOT vehicles.

*C/F=**C**urrent plans (within next 1-2 years)/**F**uture plans (beyond 2 years)

3.5.3 Implementation Plan

The integration strategies can be grouped into the following seven implementation tasks or projects:

1. **RWIS Expansion** - Expand RWIS coverage throughout state, and multiple corridor RWIS projects. Start by doing a gap analysis, and seek input from District Maintenance offices to determine desired locations. With that, WYDOT can develop an RWIS expansion plan, and

budget for new RWIS on an annual basis to complete the desired expansion in approximately the next five years.

2. **AVL/MDC** - Expand vehicle weather data transmission to TMC from plows with AVL/MDC. This will include continued deployment of their current AVL system statewide. For the MDC component, WYDOT will use its systems engineering process to ensure all requirements are met, including integration with the current AVL system.
3. **Weather Information Manager (WIM)** - Employ part time, contracted meteorologist as weather information manager. This individual will help implement much of this plan, assist the TMC operators in managing and utilizing current and future weather information, and provide a primary point of contact for all weather information resources within WYDOT.
4. **VSL Expansion** - Add Variable Speed Limit (VSL) in four locations and continue to expand in statewide corridors. One of these four new corridors, a VSL project in the Rock Springs - Green River corridor on Interstate 80, was completed and became operational on January 31st, 2011. Two more of these four will be operational by October 2011, and the fourth corridor is currently schedule to be constructed in 2012.
5. **Weather Information Tool** - Build integrated weather information tool to assist operators. Deploy portions of this for commercial vehicle and general public use. The weather information manager will be instrumental in developing this system. That person will also be responsible for keeping the information in this tool timely and accurate.
6. **Weather Alert Notification** - Expand/enhance alert notification system in phases: 1) using SCAN Sentry 2) expanding METalert system 3) using the new integrated weather integration tool/database. SCAN Sentry is presently available to the TMC; it just needs some fine tuning on the configuration and some additional training for the operators. METalert is also available, but additional features (e.g. visibility alerts) could be very useful for the TMC operators.
7. **ATMS Decision Support** - Expand decision support tools, starting with VSL and moving to DMS recommendations. This will include some software development work for our existing ATMS to provide such recommendations based on weather and traffic information.

Table 18 shows the schedule and estimated cost (initial and O&M) for each of the seven projects identified above.

Table 18. Project Timeline and Costs

Project	Start	Completion	Initial Cost	O&M Cost
RWIS Expansion	Ongoing	2015	$ 2,000,000	$ 400,000/year
AVL/MDC	2011	2017	$ 800,000	$ 100,000/year
WIM	Ongoing	N/A	N/A	$ 100,000/year
VSL Expansion	Ongoing	2014	$ 3,000,000	$ 200,000/year
Wx Info Tool	2011	2013	$300,000	$15,000/year
Wx Alert Notification	Ongoing	2013	$20,000	$3,000/year
ATMS Decision Support	2011	2013	$150,000	$15,000/year

Many of these projects are underway and at least partially funded. The scopes of these projects may need to be slightly re-defined to meet the needs identified in WYDOT's plan.

3.6 Redding, California TMC

The Caltrans District 2 TMC located in Redding, California is the second Tier 2 TMC that received limited support for their integration planning. They conducted their self-evaluation using the Guide, and identified a set of weather information integration strategies consistent with their indicated priority needs. However, the pressing immediate demands on their time and resources to operate the TMC did not allow them to prepare an integration plan.

The Redding TMC identified a list of weather information integration strategies that are presented below. It is uncertain whether these strategies will be implemented at the TMC.

3.6.1 Weather Information Integration Strategies

Table 19 provides a summary of Caltrans District 2 TMC integration strategies. The table shows their current level for each integration item, the recommendation from the self-evaluation guide, the integration level selected by Caltrans, and comments for each integration item. Their chosen weather integration level by integration item was fairly conservatively identified due mainly to extremely constrained resources to support implementation. As shown in the table, many of the integration items were not addressed and would need to be considered as possible future items.

Table 19. Summary of Integration Strategies

Integration Item	Current Integration Level	Guide Recommended Integration Level	Chosen Weather Integration Level	Rationale/Comments
1: Use of Internal Weather Information Resources	3	4		Possible future consideration
2: Use of External Weather Information Resources	3	4		Possible future consideration
3: Availability of Weather Information	3	4		Possible future consideration
4: Frequency of Weather Forecasts	3	4		Possible future consideration
5: Frequency of Weather/Road Weather Observations	2	4	3	Bring more Wx info, more often, into the TMC.
6: Weather Information Coordination	none	4	1	Combine with Item 8. Establish coordination committee within the TMC.
7: Extent of Coverage	4	4		Possible future consideration
8: Interaction with Meteorologists	1	3	2	Combine with Item 6. Establish relationships with NWS and obtain assistance.
9: Alert Notification	2	4		Possible future consideration
10: Decision Support	1	3	2	Prepare quick reference flip cards
11: Weather and Road Weather Data Acquisition	3	4		Possible future consideration

4.0 Implementation and Evaluation of Sacramento RTMC Weather Alert Notification System

The Caltrans District 3 Regional Transportation Management Center (RTMC) has been participating since 2007 in the FHWA weather information integration study to identify strategies to enhance TMC weather integration in support of operations, to implement selected strategies, and to participate in an evaluation of the results of their strategy implementation. The RTMC has utilized the FHWA TMC Weather Integration Self-Evaluation and Planning Guide and also prepared a weather integration plan. This section focuses on a strategy they implemented to integrate road-weather information into the RTMC operational advisory functions by implementing an automated weather alert notification system. This system is expected to provide timely traveler and road weather information to the public, particularly regarding fog, wind and frost conditions that can severely affect travel safety and mobility. This section briefly summarizes the implementation and evaluation of the system. A separate, stand-alone report[6] provides more detailed information on those efforts.

4.1 Sacramento's Weather Information Integration Plan

The Sacramento RTMC identified the following weather integration strategies using the Guide:

1. **Frequency of road weather observations** – identify the time intervals for collection of environmental sensor station data. This will reflect the level of detail for information that is required by the RTMC for decision making.
2. **Extent of coverage** – identify additional observations beyond the present environmental sensor station coverage that are required to provide the needed weather information for various road weather conditions to support RTMC decision making.
3. **Weather information coordination** – assign responsibility to an RTMC staff member for coordination of weather information/integration related activities, including training.
4. **Alert notification** – provide automatic alerts to RTMC personnel (and potentially others) when certain weather condition thresholds are exceeded.
5. **Road weather data acquisition** – identify the road weather data, including forecasted road weather conditions, needed to support RTMC decisions. Additionally, identify the level of technological sophistication needed to process and manage weather data.

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[6] Cluett, C. and Kitchener, F. (2010). *Implementation and Evaluation of the Sacramento Regional Transportation Management Center Weather Alert Notification System.* (Report No. FHWA-JPO-10-063. NTL No. 14969). Washington, DC: Federal Highway Administration.

6. **Use of external weather information sources** – identify the appropriate weather information sources, observed and predicted, not owned by the RTMC or other state agencies. Additionally, identify the integration techniques to incorporate these information sources into the RTMC decision-making processes.
7. **Decision support** – identify procedures and tools to integrate road weather information into the RTMC decision making processes.

There are overlaps among each of these strategies, and these interrelationships are an important consideration when planning implementation tasks. The Sacramento RTMC's primary goal was to provide alert notification to their operators regarding existing weather conditions so that more effective public advisory notification actions could be taken in a more timely manner. The other strategies listed supported that goal. It was also decided to focus the weather integration strategies on operations associated with the Sacramento Valley.

4.2 Alert Notification System Implementation Objectives

In order to enhance their operational performance, particularly during severe winter weather events in the Sacramento Valley, the RTMC implemented a series of activities in 2009 to achieve the following five main objectives:

1. Improved coordination of operator response and decision making regarding the posting of traveler advisories during severe weather conditions;
2. Enhanced weather information coming into the RTMC;
3. Implementation of an automated alert notification system that would improve operational awareness of and response to severe weather;
4. Refined operational procedures to guide efficient and appropriate operator response to weather conditions; and,
5. Development and implementation of a training program to enhance awareness and strengthen the capability of operators to proactively use weather information, weather warnings and alerts in RTMC operations and in posting and removing advisory messages.

4.3 Alert System Implementation Tasks

The RTMC management committed to implementing the weather alert notification system through a series of tasks carried out during 2009, as follows:

1. Identify and assign an RTMC weather coordinator.
2. Identify weather information sources (observations and forecasts) and determine what is needed in addition to sources already available and access by the RTMC.
3. Properly calibrate and maintain Caltrans-owned road weather observation sensor sites.
4. Identify, procure and install additional weather observation systems.
5. Define alert mechanisms and thresholds, procedures, and timing.
6. Implement the weather alert notification system.
7. Define and implement a training program for operators and others.

Responsibilities were assigned, a schedule was established, and by December 2009 automated weather warnings and alerts were being delivered to operators 24/7 in the RTMC.

4.4 Evaluation Approach

Quantitative and qualitative data were collected to support evaluation measures in both the baseline ("before") and post-deployment ("after") periods. The quantitative data included weather condition readings from a set of RWIS sensors, records of warnings and alerts issued before and during weather events, information on messages posted on electronic signs in the valley, and operator entries in the Computer Aided Dispatch (CAD) TMC logs. The qualitative data were obtained through interviews with operators and managers of the RTMC, and they included observations and perceptions of changes and benefits being derived from the implementation of the weather alert notification system, and also institutional and organizational benefits received as a result of using this system. Data were collected throughout the baseline period of the implementation, and again after the strategies had been implemented and were operational for a period of time.

The evaluation focused on a few significant weather events during which the alert notification system was active. These events were analyzed in detail to understand how well the warnings and alerts tracked the actual weather conditions and how well the operators were able to use those warnings and alerts in supporting their decisions to post messages for the public. The evaluation also addressed the institutional process by which management sought to implement the system, make adjustments based on their real-time experiences with the system, and incorporate feedback from the operators.

The evaluation analysis compared outcomes between the "before" and "after" periods as a basis for identifying changes and benefits that could be attributed to the new integration strategies. Lessons learned were derived from the total implementation experience for the benefit of Caltrans and other TMCs that are considering enhancing their own level of weather integration.

4.5 Baseline Conditions and Challenges

The information collected during the baseline evaluation period identified needs that were closely aligned with the selection of weather integration strategies the RTMC intended to pursue and the tasks identified in their Implementation Plan. Table 20 below summarizes the primary baseline condition findings and corresponding implementation plan tasks that addressed these issues.

Table 20. Summary of Baseline Conditions and the Relationship to Implementation Plan Tasks

Baseline Conditions and Challenges	Implementation Tasks
General lack of focused and coordinated use of weather information.	Task 1: Identify and assign a RTMC weather coordinator.
RWIS sensors inaccurate and unreliable. No confidence in sensor data.	Task 3: Properly maintain/calibrate Caltrans RWIS data stations.
Lack of knowledge of all possible weather information sources that could be used to identify or confirm weather events.	Task 2: Identify weather information sources (observations and forecasts) available or accessible.
Lack of coverage of sensor data, mostly in areas that experience dense fog.	Task 4: Identify, procure, and install additional weather observation systems.
Too much dependency on field personnel to determine when a weather event begins and ends – their input is not always accurate or timely.	Task 5: Define alert mechanisms, thresholds, and procedures. Task 6: Implement weather alert system.
Lack of procedures or guidance regarding operations during inclement weather events.	Task 5: Define alert mechanisms, thresholds, and procedures.
Inconsistent response by the various RTMC operators during weather events.	Task 7: Define and implement training program.
Difficult to know when a weather event is beginning.	Task 6: Implement weather alert system.
Difficult to know when a weather event has ended.	Task 6: Implement weather alert system. (Note: future enhancements to the alert system are planned to address the issue of when events end.)
Significant delays between when an event begins and when signs are activated	All Tasks: Implementation of a weather alert system, operator training, and consistent use of operational procedures.

4.6 Alert Notification System Implementation

The RTMC management decided to build their automated alert notification system by activating a feature of the SCAN Web[7] system (called SCAN Sentry) that issues email alerts when certain conditions (weather data thresholds) are met. This approach is limited to the six RWIS station locations in the Sacramento Valley and was selected as the easiest and least costly way to get an alert system up and running. The RTMC management saw this as a way to test and demonstrate how an alert system might help the operators, with the thought that it could be expanded in the future if it

[7] SCAN Web® is a registered trade mark of Surface Systems, Inc.

proved successful. The results of this evaluation will help the RTMC management decide if an expanded alert system is required to continue improving weather responsive operations.

The following is a summary of how the implemented alert system works:

1. Weather data from the six RWIS stations identified in Task 2 are posted every 10 minutes to the SCAN Web database. This includes all sensor data available at each location.
2. The SCAN Sentry system (software routine with access to the SCAN Web database) compares the weather measurements to the established warnings and alerts. The warnings and alerts identified above were incorporated in the SCAN Sentry system by RTMC management.
3. When the warning or alert conditions are met based on established thresholds, an email is sent to RTMC management and operators.
4. The SCAN Sentry system allows the manager to limit the number of alerts issued if the conditions persist. The maximum time (suspend time) between alerts is 3 hours. If a wind event continues to exceed (or repeatedly fluctuate through) the threshold for several hours, or even days, the operator will continue to receive alerts every 3 hours (but, not every 10 minutes).
5. The SCAN Sentry system does not have the capability of issuing an alert when the thresholds are no longer met, or not met for a given period of time, so operators are not alerted when weather conditions drop below thresholds. This is a limitation that the RTMC management would like to rectify with a new alert system in the future (second approach above).

The SCAN Sentry alert system was activated in the fall of 2009 and began issuing warnings and alerts based on the established weather data thresholds.

4.7 Alert Notification System Performance

Four significant fog and wind events that occurred between December 2009 and April 2010 were selected for a careful assessment, as case studies, of the performance of the weather alert notification system. These included:

1. A fog event that occurred December 17-18, 2009. While fog persisted throughout the valley over these two days, visibility conditions actually dropped below the indicated threshold in two distinct periods such that, for the purposes of assessing messaging performance, this can be interpreted as two separate fog events over this period of time.
2. A particularly severe and persistent wind event that occurred January 17-21, 2010, resulting in 176 alerts being issued.
3. A wind event that occurred March 12-13, 2010.
4. A wind event that occurred April 27-28, 2010.

Each event was evaluated with regard to 1) the timing and duration of the event, trends in the weather measure (sight distance for fog, average sustained speed and gust speed for wind, and temperature for frost) and when those measures crossed their pre-defined threshold, 2) the timing of issuance of automatically generated warnings and alerts that were received by RTMC operators via email, and 3) the timing of traveler advisory message activation and deactivation by the operators during the event. In assessing the RTMC operator responses to these weather events, several indicators were considered:

- Were the warnings and alerts issued appropriately and according to the designated thresholds?
- To what extent was the event covered by messaging to the public?
- Were the appropriate message signs activated based on receipt of alerts and readings from the various sensor sites?
- Were signs deactivated in an appropriate and reasonably timely way?
- Did the operators record information about the event and their decisions in the TMC log?

Follow-up interviews were conducted with four of the RTMC operators in June 2010 after they had experience with the weather alert notification system. The purpose of this interview was to learn how the alert system has been working from the operators' perspective. Some of the same questions were addressed for this interview as had been covered in the baseline interviews conducted a year earlier. Operators in the follow-up interviews were asked to describe how they used the new alert system and whether it was helpful to them in improving the efficiency of their messaging decisions. The new procedures were discussed along with the factors operators consider when making advisory decisions. The analysis of some of the weather events from this evaluation were shared with the operators.

4.8 Evaluation Findings and Lessons Learned

The evaluation of the Sacramento RTMC weather alert notification system examined several adverse weather events in some detail in order to assess quantitatively how the alert system was performing and how the operators were able to use it in supporting their operational decisions regarding posting of advisory messages. The quantitative analysis focused primarily on the post-implementation data obtained from the RWIS sensors, the alert system records, and message sign records. Qualitative findings are based on interviews with selected operators before and after the implementation of the alert notification system.

The quantitative findings include the following:

- **Timeliness of Alerts**. Alerts should be issued to coincide with the start of an event, when conditions exceed the defined threshold. Across the four event periods analyzed, alerts were issued for the most part in a timely and accurate way; that is, 16 out of 18 times (for individual RWIS sensors) they were issued within +/- an average of 10 minutes of the time when the weather condition broke its defined threshold value at the beginning of the event. This is virtually right on time, given measurement error. **Interpretation:** The alerts were mostly well timed, indicating the alert notification system was working as planned.
- **Timeliness of Message Activation.** The RTMC aims to have messages posted on appropriate message signs for the duration of a weather event that exceeds the defined threshold. Fifteen individual sensor-reported weather events that exceeded threshold and/or lasted longer than 16 minutes should properly have had weather warning messages posted throughout those events; 13 of them did and two had no messages posted. For those event segments with some message coverage, coverage ranged between 27% and 100% of the

duration of the event. Out of the 13 events with message coverage, 11 had coverage over 75% of the duration of the event. **Interpretation:** Messaging coverage was generally good but not complete. However, coverage improved over the duration of the evaluation from December 2009 to April 2010, suggesting that the alerts were helping operators post messages more appropriately.

- **Adequacy of Messaging Coverage.** The second dimension of messaging adequacy related to the posting of messages triggered by sensor alerts on the primary signs near the sensor site. As discussed in this report, there are a number of mitigating circumstances that might reasonably prevent posting weather messages on some of these signs. For example, during road emergencies the signs may be needed for traveler alerts, and during mountain snow events, some valley signs may be used for chain control advisories. Nevertheless, across all these case study events, the number of CMS, EMS and LED signs used was significantly less than the number of signs recommended in the RTMC policy guidelines. For the December fog event, out of 8 opportunities to activate primary signs for significant events, only 2 were used, along with 2 out of 8 secondary signs. For the three wind events taken together, out of 43 opportunities to activate the primary signs for significant events, 12 were used (28%). However, the ratio of messaging on primary signs improved over time, with 7 out of 17 (41%) used in the April wind event. **Interpretation:** A low number of primary message signs had messages posted during the weather event case studies examined, but coverage improved over the course of the evaluation period, presumably due to the operators' increasing familiarity with and understanding of the new procedures.
- **Timeliness of Message Deactivation.** Once a message has been posted advising the traveling public about an existing severe weather condition (e.g., dense fog, high winds, frost on road), the operators need to periodically monitor conditions. They need to remove the message after the weather condition has abated and it is reasonable to assume it is not about to return to threshold conditions soon. This is a judgment call, as the alert notification system does not provide explicit guidance regarding when a weather event is over. The alert notification system will continue to provide warnings and alerts in three hours or longer intervals as long as the weather conditions persist, which is helpful to the operators in maintaining their awareness of the status of these conditions. It is considered prudent to leave a message active for a while as conditions are improving in order to avoid frequently activating and deactivating messages. On the other hand, leaving a weather warning message posted long after the event is over may lead to a loss of public trust in the messages. The RTMC management is considering how their alert notification system might be able to issue an "all clear" signal based either on the length of time that passes after last crossing the threshold with an improving trend or the time when conditions reach a designated level after last crossing the threshold.

  For 14 sensor-covered event segments for which messages were activated among the four case studies, the period from the end of the event to message deactivation ranged from 18 minutes to 8 hours and 44 minutes. This extended period of message activation equaled an average lag time of 4 hours and 14 minutes. This is the average period of time during which a message was posted on a roadside message sign indicating an adverse weather condition after that condition no longer exceeded the defined threshold. Without knowing the detailed circumstances associated with each of these events, it is not appropriate to make a definitive judgment about them. For example, operators often rely on CHP in the field to verify conditions for activating messages, but after the weather has improved, CHP is usually no longer available at those locations to advise the operators to deactivate the message.

Interpretation: While the RTMC has not specified an appropriate amount of time to leave a message actively displaying an advisory about weather that has since subsided, nor implemented alerts to signal that time for the operators, the experience with many of these sensor-covered event segments shows there were a number of periods during which messages were left active much longer than needed or desired.

Findings from the qualitative interviews conducted in the baseline and post-alert periods included the following:

- In the baseline period the operators reported they would like to have more frequent weather updates. They also said they lacked adequate weather readings for some important locations in the valley.
- In both the before and after periods, operators expressed less than high confidence in the quality and accuracy of the weather data they were receiving in the RTMC. They uniformly said it was critical to confirm either data from sensors with human observations or readings from other sensors, or human observations with sensor readings. This follows management guidance that all weather data be verified with one or more additional sources before making a decision to post a travel advisory message. They did, however, perceive that sensor data quality had improved over this period.
- Operators in both periods felt that operating procedures and guidelines for making decisions based on reported weather conditions were less than adequate. Some said they desired additional training and consistent information on how to respond to the weather data (observations and forecasts) that they receive in the RTMC. Other experienced operators felt they knew how best to perform their job responsibilities without need for additional management oversight.
- RTMC operators want to be proactive with regard to weather. They want to be aware of impending weather conditions likely to affect traffic in advance if possible so that they are well prepared to respond in an appropriate and timely way. However, they feel that in practice they tend to primarily be reactive to weather, and as long as they receive the information they need in a clear and timely way, they respond appropriately.
- In the baseline period the operations floor was staffed most of the time with two operators who then could share the workload. In the later period after furloughs and staff reductions, there was typically only one operator. This meant responses to weather events had to take second priority to higher priority safety matters, and there would be response delays due to very busy shift activity.
- The operators valued the warnings and alerts that were available to them in the post-implementation period, though they felt it necessary to verify their accuracy before taking any actions based on them. They said the automated alert system has made them more aware and allowed them to be more responsive to events as they unfold.

Several lessons can be drawn from this evaluation of the experience of the Caltrans District 3 RTMC and their efforts to establish and refine an automated weather alert notification system. What has been learned, and continues to be learned, as this system matures and becomes more a part of the operating procedures of the RTMC, can be helpful to both Caltrans and other TMCs across the country as they explore ways to integrate weather information into their operations. These lessons include the following:

- **Operator training is essential for successful weather integration.** Both the RTMC management and the operators recognized the importance of training to help assure a well informed and consistent use of the new weather alert notification system. Providing this training to all the operators as a group has been a challenge in the face of the recent staff reductions and furlough policy enacted by the State of California. The training content should include clear operational policy guidance along with conveying to the operators an understanding of the system upgrades and changes, how and why they have been made, and how these affect the weather information flowing into the RTMC. A challenge is to strike an appropriate balance between the level of specificity in operational guidance for taking action in response to weather, and providing flexibility for the operators to use their experience and judgment in making decisions about their advisory and control actions.
- **Alert notification procedures need to be clearly and consistently specified.** It is important that the thresholds for issuing warnings and alerts that are programmed into the notification system be consistent with the specifications communicated to operators in the written procedures and training jnstructions, and that the operators understand and follow these procedures. The Caltrans District 3 procedures call for operators to verify an alert with information from adjacent RWIS sensors, available third party weather services (NWS, AccuWeather, local weather reports, etc.), and/or field observers (typically CHP, sometimes general public calling in). Reconciling differences among these information sources about a particular weather event condition takes experience and judgment on the part of operators. Procedures and training must account for the complexity of operator decision making based on information of varying accuracy, reliability and geographic focus.
- **A successful demonstration of an alert system depends on a well-integrated system.** The Caltrans District 3 system is built off of their existing SCAN Web software that monitors data from RWIS sensors and can be programmed to issue warnings and alerts when pre-defined weather condition thresholds are reached. The success of this system depends on accurate and reliable weather data from the sensors, appropriately defined threshold conditions, clear communications of alerts to the operators, procedures in place that guide operator responses, and operator training and buy-in to assure effective use of the information. The RTMC management has remained flexible and responsive throughout this demonstration period to understand where their alert notification system could be fine-tuned and improved as they experienced its use under various weather events. This has provided a foundational experience upon which they can consider a more robust alert system for the future that adds features and capabilities that are not currently available with existing hardware and software. For example, adding new strategically located sensors, upgrading the weather detection capabilities of the sensors, adding better detection and notification of the end of a weather event, adding possible visual and auditory notification in the RTMC, and refining their procedures, are all candidate improvements that have been identified in the course of operating the current system through this weather integration demonstration.
- **Time and resource constraints affect the performance of an alert notification system.** The State of California is experiencing a severe economic downturn that has resulted in reduced staffing and furloughs among TMC management and operators. This has raised the stresses associated with getting the day-to-day work done and made it more difficult to integrate the weather alert notification system into TMC operations. Operators have competing priorities and fewer staff to meet these responsibilities. Management faces similar constraints, resulting is less time to focus on new weather integration initiatives such as the alert notification system. TMC management also is constrained by time consuming procedural requirements of Caltrans associated with the implementation of new projects.

> These kinds of constraints need to be anticipated and understood when implementing new systems like this and contingency plans developed to overcome the constraints. There were several planned activities that were not accomplished due to funding or time constraints, including installing new RWIS sites and developing a more sophisticated alert system with enhanced capabilities. Based on the progress made to date, the RTMC management intends to improve their alert system as new funding can be secured.

In implementing the weather alert notification system, management developed a good step-by-step implementation plan that has guided them through the process. A critical task early in this process was to engage a contractor to calibrate the RTMC’s field sensors. In the baseline period the operators reported having very little confidence in the data they were receiving from the sensors. After sensor recalibration and implementation of the alert notification system, operator confidence improved, though there remained some carryover of the perception that these data were still suspect. Operator training can help overcome such skepticism by explaining clearly what has been done to improve the data quality in the system and providing evidence that shows these improvements.

The use of the TMC logs offers a good example of how operators are learning to work with the alert notification system. The new procedures have emphasized the importance of making log entries that document and explain the actions operators have taken in response to receipt of the alerts, and the operators’ logging performance has improved over this period. RTMC management also has made good progress implementing this system and responding in real time to the need for mid-course adjustments, refinement of procedures, and oversight of the operators. The evaluation process has served to identify ways the notification system, and the institutional support for the system, could be refined, and the result of this collaborative interaction with the RTMC is reflected in the benefits being derived from the alert notification system. Ultimately, it is the traveling public that is the beneficiary of these RTMC system innovations in terms of enhanced mobility and safety during periods of inclement weather and dangerous road conditions.

5.0 Strategic Marketing Plan

As a generalization, weather integration is currently at a relatively low level in most TMCs across the country. In many TMCs it is nonexistent at this time, even though weather, in some form, is affecting transportation safety and mobility everywhere. In addition to the technical tasks that involve working with a small set of TMCs, the strategic marketing efforts focused on activities aimed at increasing the awareness and capabilities of TMCs for integrating weather information in their daily operations.

5.1 Approach

Effective marketing helps TMC operators recognize the importance of road weather information in their operations, understand and use available tools to assist them in better managing weather-related events, and proactively seek out and access other resources in support of more effectively interpreting weather phenomena in the context of their transportation mission. Ultimately, the RWMP's goal is that TMC managers and operators fully embrace a culture that proactively uses new technologies and strategies for dealing with inclement weather.

A strategic marketing plan was developed as part of this task. The plan identified the primary and secondary audiences, the key messages to be conveyed, the challenges to be overcome, and the benefits of weather information integration. The plan also contained an itemized list of activities that supported the marketing efforts. Over the course of the project, various activities were conducted based on the plan.

5.2 Audience for Marketing

The primary audiences to reach via marketing efforts are the state DOTs and their statewide and local TMCs. TMC managers, operators, and staff are the primary audience for the Guide. TMC staff include individuals involved in weather-related activities such as maintenance and public safety. The secondary audiences include:

- Operations staff at FHWA Division Offices and Resource Centers. These operations staff need to be aware of the Guide so they can promote it and help the agencies they serve implement it.
- State DOT executive management, including senior State DOT traffic and maintenance managers. These managers need to be informed about the benefits of weather integration, as they can allocate resources and control the budgets at TMCs.
- Private consultants. Most TMCs and state agencies engage consulting services. Private consultants need to see the value in using the Guide to help the TMCs structure their planning efforts. Alternatively, TMCs may also want to use consultants to support them in their self-evaluation, planning and implementation activities.

- Weather information service providers. Providers of weather information are a secondary audience for the Guide as they can provide input to the integration strategies and planning portions of the Guide.

5.3 Marketing Activities Conducted

Over the past two years, a variety of marketing activities guided by the plan have taken place. Primarily these have involved presenting at conferences and stakeholder meetings. A webinar on Weather Integration was held through the National Transportation Operations Coalition web-forum and was attended by 100 transportation professionals. The electronic version of the Guide was downloaded over 30 times after the webinar. Table 21describes the various marketing activities that were completed in the past year.

Table 21. Weather Integration Marketing Activities Conducted during Phase III

Product	Description/Locations	Status	Start	Complete	Responsible Team Members
Flyer 2-page description of Guide	RWMP Website	Completed/ Updated	Oct-08/Mar-11	Nov-08/Mar-11	Cluett/ Gopalakrishna
PowerPoint Presentations Presentations on the Guide, use, results of self-evaluation and planning process	TMC Pooled Fund meeting (Nashville, TN, 2008)	Presented	Jul-08	Jul-08	Cluett
	TMC Pooled Fund Meeting (Nevada, July 2009)	Presented	Jul-09	Jul-09	Jimmy Chu
	ITE Technical Meeting (August 2008)	Presented	August 20, 2009	August 20, 2009	Alfelor
	ITS America Annual Meeting (2009)	Presented	Jun-09	Jun-09	Alfelor
	ITE Annual Meeting (2009)	Abstract Not Selected	Aug-08	Aug-08	Cluett
	Clarus/MDSS Stakeholder Meetings (August 2009)	Presented	Sep-09	Sep-09	Cluett
	Rural ITS Conference (August 2009)	Presented	Aug-25-2009	Aug-25-2009	Kitchener
	TRB Annual Meeting (January 2010)	Presented	Jan-10	Jan-10	Cluett/ Gopalakrishna
	ITS Heartland Annual Meeting 2010, Omaha, NE	Presented	March-30	March-30	Nancy Powell KC Scout
	ITS America Annual Meeting (2010) ITS Surface Transportation Weather Committee Meeting - (Houston, TX)	Presented	May-10	May-10	Cluett

Product	Description/Locations	Status	Start	Complete	Responsible Team Members
	Clarus/MDSS Stakeholder Meetings 2010 (Indianapolis)	Presented	Sep-10	Sep-10	Cluett/Powell (Battelle/KC Scout)
Webinar Describing the self-evaluation Guide development and process along with presentations from TMCs who have completed the self-evaluation	National Transportation Operations Coalition (NTOC)	Completed (98 attendees)	Aug-6-2009	Aug-6-2009	Battelle Team
Guide Availability Announcement Short paragraph in electronic newsletters and websites indicating availability of Guide on the RWMP website	RWMP website	Ongoing	May-09	Ongoing	
Short Articles 2-3 page articles describing the evolution of the self-evaluation Guide, the steps involved in self-evaluation, experiences of the TMCs involved, case studies and success stories, and next steps for weather integration	Public Roads (Printed)	Completed	Jun-10	Dec-10	Roemer Alfelor and David Yang
Other activities Tracking downloads of the Guide and following up with downloaders for Guide feedback	Roemer sent email to everyone who visited the Guide website at FHWA. Battelle followed up with the only respondent, WSDOT	Open ended	17-May 10		Roemer Alfelor and Battelle team

5.4 Results of Marketing Approach

Overall, the marketing approach resulted in a broad dissemination of the concepts of weather information integration and shared the experiences of the various TMCs engaged in this project. Quantitative numbers are difficult to track and in some cases may be realized only at a later date. The outputs of the marketing and outreach effort identified to date include the following:

- There were over 70 downloads of the Guide following the webinar held on August 6, 2009. Of the 70 downloads, 37 of these were from MPOs, TMCs or state DOTs in the country. The remainder of the downloads were from private consultants, universities, and non-US entities. Only one state DOT representative responded to an inquiry sent to all those who visited the Guide website and left contact information. Additional follow-up is needed to understand whether other TMCs may have conducted self-evaluations and implementation of integration strategies.
- Over 10 presentations were made at various conferences and stakeholder groups on the project by team members and FHWA.
- A Public Roads article published in January 2011 for managing traffic operations during adverse weather events (authored by Roemer Alfelor and David Yang of FHWA) contained a subsection on weather information integration drawing upon results of this study.
- Over 23 TMCs were contacted as part of this study to participate in self-evaluation efforts, and the final participants were selected from that initial list of contacted TMCs.
- A total of six (6) agencies have completed the self-evaluation process. All but one of them have developed integration plans.
- Four (4) TMCs (Sacramento, Kansas City, Wyoming, Colorado Springs) are starting to implement their integration plans/strategies.
- Wyoming TMC and Kansas City Scout have made presentations to other peer groups (ITS Heartland, *Clarus*/Maintenance Decision Support System (MDSS) stakeholder groups) about the benefits of weather information integration and the self-evaluation process.

5.5 Challenges in Marketing Weather Information Integration

Ongoing marketing activities for the weather information integration will likely have to overcome a number of challenges. These include challenges associated with TMC willingness to consider weather integration, to invest in the effort required to make integration successful, and to understand and use the Guide effectively. Recognizing these challenges and preparing to overcome them will be essential to a successful marketing effort. The main challenges and some approaches to overcoming them are outlined below:

- *Lack of interest in weather integration.* This may be due to a lack of awareness or understanding of data, services and technologies now becoming available that can support weather integration and contribute to more effective operational decisions. Many TMCs have said they "have what they need in terms of weather information" and are unaware of the immense opportunity offered by new weather information sources for traffic management. Continued championing of the cause of weather integration by the RWMP coupled with peer to peer exchanges can greatly increase interest in this topic. Repeated presentations by TMC managers about the success of weather integration offer a powerful way to build awareness and acceptance, and bring this concept into operations.

- *Lack of staff and budget resources to support planning for future integration.* TMC operators and staff are already exceedingly busy and are reluctant to take on more responsibilities. It will be essential to demonstrate that integration is cost-effective and can lead to work efficiencies. As the experiences with the Guide revealed, weather information integration does not need to be expensive. Most of the TMCs were able to identify immediate and low cost actions to increase the role of weather information in decision-making for their TMC.
- *Too many barriers to implementation of recommended strategies.* This may include lack of budget to implement, lack of support from upper management, or insurmountable issues with their IT departments. The current fiscal environment makes it difficult to promote new ways of operating. Agencies want to see evidence that the benefits significantly exceed likely costs before committing even to planning for new technologies or procedures. Again, success stories and peer to peer exchanges will be critical in overcoming some of these barriers.
- *Reluctance to change operational procedures.* Organizations with long-standing procedures that work well for them are resistant to making changes, and effective integration usually implies new organizational procedures, responsibilities, staff roles, and interactions with other entities. The use of the Guide and the consensus-building nature of the tool can help overcome the reluctance to change operational procedures. For example, in Colorado Springs the weather integration planning meetings resulted in Colorado DOT and the city sharing a weather information resource about which the city had been unaware.
- *Traffic operation is traditionally reactive.* Effective weather integration implies a proactive posture toward traffic management and operations that takes account of advanced information on impending weather conditions and likely impacts on the transportation system. Changing a predominantly reactive culture to a more proactive approach will be difficult. Good examples of proactive operations, informed by weather information, and coupled with time to develop and become comfortable with new procedures will help move this forward.
- *Reluctance to "think outside the box."* It is difficult for TMC operators and managers to imagine the gaps in their operational functions or what new functions might be possible given enhanced weather integration. Effective marketing needs to paint a clear picture of the operational possibilities along with the benefits of integration.
- *The self-evaluation and planning process appears too complex.* TMCs may feel that the Guide will not fit their special circumstances. The challenge is to market the Guide as a process that can be implemented by any TMC and tailored to their special needs. Resources are available to assist TMCs with a process that is sensitive to the many differences and unique aspects of TMCs across the country. A feedback process is part of the Guide, and suggestions for improvement are encouraged. The Guide is being continuously improved in response to user experiences.

6.0 Refinement of the Self-Evaluation and Planning Guide

The development of the self-evaluation and planning guide was a cornerstone of the weather information integration project. The Guide, as described in the previous sections, is a standalone Microsoft Access database application with a companion written document version. This section provides feedback from the TMCs on the Guide and presents options for further refinement and updates of the Guide.

6.1 Feedback and Changes Suggested by Users of the Guide

The TMC representatives who participated in this project appreciated the thoroughness of the Guide content, clarity of instructions, and the applicability of the integration strategies presented. Specific feedback was requested and obtained based on the use of the electronic version of the tool. The Guide was updated and improved based on the suggestions from the users. Table 22 provides a tabular summary of the changes requested by the TMCs and the changes implemented in the Guide.

Table 22. Changes to the Guide Based on User Feedback

Reason for Suggested Change to the Guide	Description of Change Implemented
Need header and footer in reports that users can print out based on user inputs. This will help when TMCs are printing multiple Guide section reports for multiple regions (such as in Louisiana) or having individuals fill out the Guide separately and then print it.	Added a form at the beginning of the Guide to allow users to enter the following: • Created By • TMC Name • Region of Interest • The information is included as the page footer in all the reports created.
Need additional sections in the Guide after Section 6. Currently, the TMCs get through the self-evaluation process and find themselves overwhelmed by the number of strategies presented to them. Need a structure that allows TMCs to further prioritize and narrow the set of strategies that they want to carry forward.	• This required restricting the content of Section 6. The text in the introduction section was simplified with an emphasis on the TMCs printing the reports, reviewing as a group, and testing some “what-if” scenarios. • Once the TMC has reviewed the report, the user is directed to a new sub-form with the list of strategies that they have previously selected in Section 5. The TMC can prioritize these strategies for immediate or future implementation. Two new reports were created with user-selected strategies identifying immediate implementation and future implementation.

Reason for Suggested Change to the Guide	Description of Change Implemented
Comment in Section 1: TMCs were confused about the terms "Area-wide" and "Region-wide". This confusion needs to be resolved.	• Changed "Area-Wide" to "Corridor-Specific" to be consistent with the paper version of the Guide.
Comment from a TMC in Section 2 (Question 2.1): Not clear what "Traffic Mgmt Device Impairment" means. Not clear what "Increased use of equipment/labor" means, especially compared to the next choice "increased use of in-house labor"	• Changed the wording to "Traffic Control Device Malfunction (Signals, DMS, etc.)" as recommended by the TMC. • Changed the wording to "Increased use of equipment/materials" and removed the word labor, as it was covered in the other choices.
Comment in Section 3: Does not have update button Section 4 button is next to Section 3 "Next Question" which is confusing Question 3.4 – Rephrase slightly to make clear Current Status – Default. Have the check-box uncheck itself.	• Changed the text to "Update and Move to Section 4" • Moved the Section 4 button below and created a separator between the "Next question" and Section 4 • Cannot change this element in the Guide due to the structure of the underlying table and error checking requirements
Comments on Reports: Check formatting of all reports Word or PDF versions are suitable Create new report in Section 6 with a subset of strategies that a TMC is interested in with a sense of priority.	• Checked, and revised as needed, formatting of all reports • Office 2007 includes the ability to save the files as PDF • Enhancements needed to be able to export to Microsoft Word were investigated but determined to be not easily programmable in Microsoft Access at this time. • Section 6 changes described earlier in the table
Comments on Section 7: The Guide stops abruptly and the outline is too complex. Integration Plan outline needs to be revised based on experiences with TMCs	• Changed the text in the Section 7 form to clearly articulate the purpose of the weather information integration plan. • Created a new outline for the TMCs to follow based on the previous TMCs' experiences.
Editorial: Spell out all acronyms in all the strategy descriptions Check for typos	• Went through the Guide and spelled out acronyms and fixed typos, especially for Section 3 and Section 4

The Guide was updated in June 2010 with the changes as indicated in the table above. The corresponding document version of the Guide was likewise updated. No further changes have been suggested by the TMC users.

6.2 Updating the Guide

The self-evaluation Guide has been successfully used at all the TMCs participating in this study. For an ad-hoc electronic tool designed on the fly to support the complexities of weather integration, the Guide has held up remarkably well to the variety of TMCs and their varying needs. However, it is important to realize that the Guide needs to be continuously updated as the field of weather information evolves, new technologies are developed to support weather integration, and TMCs expand their needs and vision of how to more effectively integrate weather information into their daily operations.

Technically, the Guide needs a periodic update of the Weather Information Integration Strategies and User Needs. Currently, there are 11 items of integration and 5 levels for each item. These were developed to cover the gamut of information integration options in 2008. With improving technologies and capabilities within TMCs, these strategies need to be reviewed and updated. Similarly, the user needs should be reviewed and updated to reflect the current desires of TMCs.

From a usability standpoint, major additional improvements to the Guide are limited by Microsoft Access' capabilities. TMCs have requested several usability updates that are better suited to other platforms than Microsoft Access. For example, the following suggestions identified by the TMCs would be useful but either too costly or not possible to implement in Microsoft Access:

- Translating the stand-alone application to a web-based tool will greatly enhance ease of access and repeated use of the Guide.
- Enhanced querying and what-if capabilities to understand the implications of implementing a particular user need
- Enhanced reporting capabilities, including creating reports in Microsoft Word
- Linkages to other RWMP programs and projects

7.0 Accomplishments and Lessons

The accomplishments of many of these TMCs toward the implementation of selected integration strategies are noteworthy and reflect management's recognition of the critical importance of weather to their operations and a strong motivation to better position their operations to take advantage of improved access to weather information.

7.1 Accomplishments and Outcomes

All these TMCs can point to a common set of important accomplishments achieved through their participation in the weather information integration program, as follows.

- Four comprehensive weather integration plans were prepared that serve not only to guide each TMCs future integration implementation efforts but also to offer clear examples for the benefit of other TMCs of weather integration across a range of strategies and under varying conditions.
- Each TMC established, through participation in the weather integration process, new partnerships, both internal and external to their agency that served to enhance their overall operations, provide benefit to the traveling public, and chart a pathway to improved working relationships in the future.
- TMCs acknowledged the importance of working closely with their counterparts in maintenance. Stronger relationships were established that will encourage collaborative activities and foster active sharing of weather information.
- Awareness was raised at all levels of the DOT organizations involved, from TMC floor operators and field staff to upper management, of the potential role and value of weather information to enhance the quality and content of traffic operations, and the value of a more proactive stance with regard to managing their systems before, during and after weather events.

Specific accomplishments to each of the TMCs engaged in Phase III are summarized in Table 23.

Table 23. Summary of Accomplishments and Outcome Achievement among TMCs

Implementation Accomplishments	Anticipated Outcomes and Benefits
Phase II Site: Sacramento RTMC	
Based on the self-evaluation process and recognizing the need for quality RWIS weather data, the RTMC recalibrated their RWIS equipment.	• Increased operator confidence in the quality and accuracy of weather information coming from their RWIS stations.
Established an initial automated weather alert notification system.	• As operators became more familiar with the alert system, the timing of message posting improved (i.e., messages were posted for higher percentages of time during event occurrence).

Implementation Accomplishments	Anticipated Outcomes and Benefits
Established policy guidance for operators regarding which DMS to use for alerts coming from various RWIS locations.	• Message posting better tracked the policy guidance over time, leading to more messages posted on appropriate DMS during weather events than before implementation.
Management awareness increased regarding the importance of providing operator training.	• Training for operators increased, leading to greater operator understanding of the value of the alert system and the importance of consistent adherence to messaging policy.
Management learned how to fine tune the threshold and interval settings for the weather alerts.	• Properly set thresholds yielded warnings and alerts that more accurately reflected actual weather conditions in the field • Properly set alert intervals reduced the irritation to operators of receiving too many unnecessary warnings and alerts while assuring that the warnings and alerts that were issued were appropriate.
Experience with this initial alert system provided a foundation upon which management understood the need and value of improvements to their system.	• The RTMC has very limited resources under the current economic conditions, but when resource availability improves, the RTMC intends to implement a new, expanded alert notification system. • Overall, operator confidence in making proactive weather-based notifications to the traveling public has increased.
Phase III, Tier 1: Kansas City Scout TMC	
Demonstrated advance notification of approaching weather events and presented through ATMS to operators as on-screen geo-located polygons.	• Will guide the full integration of this capability within their ATMS. • Enhanced operator awareness and preparedness to manage weather event information • Timely issuance of weather advisory messages to the traveling public • Enhanced traveler safety and mobility
Facilitated improved working relationships between TMC operations and maintenance	• Maintenance representatives sit in the TMC at the "snow desk" during weather events and are able to maintain continuous radio communication with their trucks and plows and provide real time updates via MoDOT's Winter Weather Event database. • TMC operators and the maintenance representatives in the TMC actively share weather information through the ATMS and both have direct access to the CCTV images of changing road conditions.
Compiled all possible weather data sources for future integration into their ATMS.	• Weather information ready for ATMS integration. • Highly efficient TMC operations, with an ATMS that "pushes" weather data to the desktop, versus an operator having to "pull" in weather data. • Enhanced advisory weather notifications to MoDOT and KDOT maintenance departments. • DOT maintenance, partners, and public satisfied with TMC performance with regard to weather information management • Better cross-agency and departmental communication and coordination. • Proactive regional weather coordination for widespread, multi-state events. • Ability to assess post-event data and identify trends, enabling new decision-making criteria for the TMC, its partners, and the traveling public.

Implementation Accomplishments	Anticipated Outcomes and Benefits
Identified threshold levels for severe weather event triggers, allowing automated road segment specific weather condition alerts within their ATMS.	• Future ATMS integration will utilize these thresholds to develop alert system. • Efficient and timely assignment of motorist assist and emergency response resources to problem areas. • Timely weather event creation and posting advisory messages. • Timely and updated incident reporting and travel times posted to message signs. • Timely on-scene response to weather incidents resulting in improved clearance times. • Enhanced safety and mobility for maintenance crews and the traveling public.
Assessment of localized weather conditions by expert meteorologists in real time.	• Improved interval assessment for start and end times of weather events. • Efficient allocation of available resources during weather events. • Potential for cost savings (staff time, materials, resources) and enhanced ability to modify staffing resources for anticipated weather events.
Approach developed to incorporate check boxes within ATMS for operators to provide timely reporting of weather event responses.	• Approach will be included in future ATMS integration activity. • Immediate post-event assessments of TMC efficiency and effectiveness. • Improved public relations with partners and motorists during severe weather events. • Enhanced agency and public satisfaction.
Phase III, Tier 1: Colorado Springs TMC	
Identified new sources of weather information through contacts fostered with CDOT during the self-evaluation process.	• CSTMC now receiving daily weather updates from the same source that has been used by CDOT but about which CSTMC had been unaware prior to the weather integration planning meetings.
The process of identifying the weather information integration strategies and tasks has led to refinements in CSTMC's Concept of Operations and operating procedures related to weather	• Awareness of the value of weather information and new ways to put that information to use in the CSTMC operations center has increased.
Established a plan and schedule for a pilot test of a signal timing plan, guided by weather information, in one of 16 city grid sections.	• Demonstrate the effectiveness of a weather-responsive signal timing plan, and based on the pilot test results, extend to all districts in the CSTMC jurisdiction. • Reduce the risk of intersection crashes and fatalities during adverse weather conditions. • Increase the throughput in corridors covered by the new signal timing plan during adverse weather conditions.
Phase III, Tier 1: Louisiana Statewide TMC	
Working through the Guide made the LATMC aware of the value of identifying and integrating into TMC operations all available weather information sources, such as MAP, State Police, and LSU (their RWIS).	• When completed according to their plan, a weather information coordinator will be appointed, thereby facilitating a more proactive use of all available weather information to better manage traffic and inform the traveling public.

Implementation Accomplishments	Anticipated Outcomes and Benefits
Awareness of the need to standardize policies and procedures to guide the flow of weather information and define weather advisory thresholds.	• When completed according to their plan, these actions will help assure a consistent operational response to weather conditions throughout the state (across the multiple TMCs).
Prepared a strategy for overcoming DOTD's reluctance to purchase new RWIS equipment that involves a small scale pilot test demonstration of the value of these systems.	• This pilot test, if implemented as planned (requires obtaining funding for the test equipment), can demonstrate RWIS benefits exceed costs, especially in high weather risk locations such as the Atchafalaya Bridge, Bonne Carre Bridge, and Red River Bridge locations that are subject to severe fog events.
Phase III, Tier 2: Wyoming Statewide TMC	
Expanding RWIS coverage throughout state, and multiple corridor RWIS projects.	• Improved access to weather information.
Expanding vehicle weather data transmission to TMC from plows with AVL/MDC.	• WYDOT expects challenges because the MDC component lacks a clear implementation strategy and integration with WYDOT's AVL system.
Employed a part time, contracted meteorologist as the TMC weather information manager.	• Assist TMC operators with professional interpretation of weather information and relevance to operational decisions.
Add VSL in four locations and continue to expand in statewide corridors.	• Expanded weather information integration will support extension and operation of WYDOT's VSL program.
Expand and enhance the weather alert notification system in phases.	• This activity is expected to start this year, 2011, and will improve operational response to emerging weather conditions and provide timely notification to the traveling public.
Expand decision support tools, starting with VSL and moving to DMS recommendations.	• This activity is expected to start this year, 2011, and will facilitate timely and effective decision making for TMC operations.

7.2 Lessons Learned

A review of the accomplishments achieved so far by the TMCs that have participated in the weather information integration program over the past six years illustrates a number of "success factors," lessons, and remaining challenges based on these experiences that can be expected to be relevant for any TMC. Various lessons learned have been listed in the prior reports on the earlier phases of this project, and more recently based on the Sacramento RTMC implementation and evaluation of their weather alert notification system (see Section 4). The potential value of lessons from these experiences is tied to creating a wider awareness of the benefits of weather integration and engagement in a process to identify and deploy integration strategies that can improve the operations of TMCs across the country. The ultimate benefits of weather integration are the attainment of the goals of safety, mobility, and satisfaction for the traveling public. Broad lessons, common across each of the TMCs in this study, include the following:

- TMC managers are not generally predisposed to seek out new ways to integrate weather information into their traffic operations, and often they are unaware of weather resources that exist within their broader agency. After participating in the self-evaluation and integration planning process, the TMCs in this study recognized the potential value offered by weather integration, but for the most part required considerable assistance in moving forward to incorporate new ways to integrate weather. Self-motivation sufficient to support achievement of real changes in operations based on weather integration, along with a clear understanding of the steps they needed to take, appears to be rare.

- Resources, both financial and staff, constitute a serious challenge to the successful promotion of weather integration in TMCs. While this point has been made a number of times before, it deserves repeating. This is not just a temporary problem associated with particularly difficult economic conditions in many states. TMC personnel are so stretched to fulfill their daily obligations and tasks, that motivating them to take on a new set of tasks and responsibilities, including modifying policies and procedures to support new ways of operating with weather information, is very difficult. Although TMC managers and operators may agree that enhanced weather integration could help them better meet their operational needs and serve their traveling public, weather integration simply doesn't represent a high enough priority for them among their many tasks.
- While the weather integration project has focused on enhancing TMC operations, the process depends on teamwork not only within the TMC but also with other agencies and stakeholders. Many, though not all, TMCs have separate structures for their operations and maintenance components. The most effective weather integration implies a seamless sharing of information and decision making across operations and maintenance, but the historical arrangements in TMCs often present major institutional and cultural barriers that hinder information sharing. Engagement in the weather information integration project has helped overcome these barriers where they have existed, but the motivation for TMCs and State DOTs to make that happen is lacking.

In spite of many challenges, the TMCs that have been engaged in the integration project have achieved notable progress, as shown in Table 23 and discussed throughout this report. However, in order to successfully promote and achieve more widespread TMC engagement and accomplishment with weather information integration, a number of additional steps should be considered, as recommended in Section 8.

8.0 Recommendations

This section identifies specific recommendations that define a roadmap (next steps) to continue the efforts of the RWMP to promote and enhance the level of weather information integration in the nation's TMCs. These recommendations focus on the need to build a sustainable weather integration program, effectively promote a weather information integration program with documented benefits, refine and maintain a comprehensive tool to evaluate weather information integration in a particular TMC, and identify the most technologically advanced strategies to enhance their capabilities.

Specific recommendations include:

1. Assure Progress and Sustainability of Weather Integration
2. Identify and Document Evidence of Weather Integration Benefits
3. Assure Currency and Relevance of Weather Integration
4. Refine Self-Evaluation Process and Improve Tool

Each recommendation describes the objective, rationale, approach, and outcome – providing the details to understand its importance and significance to increase the breadth of the weather information integration initiative. Identified within each recommendation is a set of activities or tasks necessary to achieve the overall objective of the recommendation. Although the recommendations are not in a priority order, there is high degree of interaction among the recommendations. Outcomes of a particular recommendation may help to inform other recommendations. For instance, the identification and documentation of weather integration benefits (for a variety of strategies) would certainly support efforts to promote the initiative's goals with TMCs that may be considering implementing weather information integration.

8.1 Recommendation 1: Assure Progress and Sustainability of Weather Integration

Objective: A goal of the RWMP is to encourage widespread awareness of the value of integrating weather information and systems into TMC operations and progress toward accomplishing that, resulting in a high degree of weather information usage in system operations and management.

Rationale: The TMC Weather Integration project has shown that significant potential exists to improve weather information integration at TMCs. Recent advances in the availability of information and improvement in traffic management approaches and technologies significantly improve the ability to achieve weather responsive traffic management (WRTM). As champions emerge on behalf of TMC weather integration, there needs to be a focused push to enhance TMCs' understanding of potential weather information integration opportunities and how they fit under the larger umbrella of WRTM. Even those TMCs that have made some headway with weather integration have difficulty visualizing the benefits of additional investments, and virtually all TMCs operate under very constrained budgets and difficult economic environments. State DOT and TMC managements want and expect clear evidence of a strong benefit-cost tradeoff before they will authorize capital investments to implement weather integration initiatives. The motivation among TMCs to pursue weather integration in the absence of on-going outside assistance is insufficient to overcome the financial hurdles and knowledge gap that hinder significant advancements in this regard. Reaching the RWMP goal without putting in place a sustainable strategy to support weather integration is going to be very difficult.

Approach: This recommendation is grounded in experience working with some of the more advanced, progressive TMCs with regard to their recognition of the importance of weather in their operations. Long-term progress incorporating weather integration into TMC operations must be grounded in a motivated TMC constituency that understands the role of weather integration in the context of WRTM, and not allowed to remain dependent on continued outside assistance. This can be achieved by a multi-pronged strategy that includes the following elements:

- Follow-up actively on the marketing strategies identified in the current program. This includes updating flyers and disseminating testimonials from TMCs that have successfully integrated weather information, and having them convince their peers from firsthand experience. Expand a database of success stories that demonstrate how weather integration has enhanced operations and provide implementation details.
- The RWMP should present weather integration as a key component of WRTM, emphasizing how weather information integration dovetails with the other key elements of the WRTM program (illustrated in Figure 1).
- Develop and actively support an institutional strategy within the RWMP to respond to TMC questions and needs with regard to weather integration. Offer training and support to the self-evaluation and integration planning process. Encourage the creation of a new working group of TMC representatives, and sponsor annual or more frequent meetings of this group that would focus on all aspects of weather integration (needs and strategy identification; integration planning; implementation approaches; performance evaluation).
- Sponsor one or more workshops with representation from all stakeholders (TMC operations and maintenance; emergency management agencies; software developers; meteorologists; etc.). Include leading weather integrators who can speak from successes.
- Work closely with and provide support to organizations or groups that include members of the TMC community or work with TMCs, such as the TMC Pooled Fund Program, the TRB, the Institute of Transportation Engineers (ITE), and the American Association of State Highway and Transportation Officials (AASHTO) and their committees and subcommittees that focus on operations and maintenance. Make presentations to these groups based on successful weather integration experiences, encourage them to focus on weather integration, and make them a part of an institutional strategy for sustainable support of weather integration.
- In the short run, actively support TMCs that express an interest in weather integration, but seek to replace such *ad hoc* responses with an institutionalized, sustainable support infrastructure.
- Engage each of the major new transportation initiatives to educate and promote with regard to weather integration and include their representatives in the new institutional mechanisms.
- Seek to overcome the traditional separation and communication barriers between TMC operations and maintenance. Encourage a proactive approach to weather integration that is open and sharing in its orientation and practice. Maintenance is currently better organized than operations, with their focus on winter pavement management issues. A good next step

would be to seek to include traffic operations in their network, meetings and conferences to seek common ground around enhanced weather information and integrated decision making.

Outcome: The outcome of this recommended set of activities would be a rapid increase of the number of TMCs that undertake weather integration activities in their operations and a growth in sophistication among TMCs that have already made some headway toward weather integration. Weather integration should become mostly self-supporting and no longer require on-going costly outside support in order to motivate adoption.

8.2 Recommendation 2: Identify and Document Evidence of Weather Integration Benefits

Objective: In order to successfully promote the weather information integration initiative and encourage TMCs to consider weather integration strategies to improve their operations, they need to better understand the potential benefits of implementing these strategies.

Rationale: Recent research has revealed very limited measurable benefits of weather information integration applications to traffic operations. The evaluation of the Caltrans D3 Sacramento Regional TMCs' weather alert system indicated how timely and accurate weather information could improve traveler information messaging. Although this analysis showed promising results, the alert system was limited and it only addressed one weather information integration strategy. Also, it addressed primarily better weather information coming into the TMC, but did not evaluate the actual integration of the weather information and how that might affect TMC operations. The RWMP needs a set of quantifiable benefits for a variety of strategies that can be shared with prospective TMCs interested in weather information integration acting as a catalyst to motivate them to perform a self-evaluation and move forward with implementation of weather integration strategies.

Approach: The completion of this project has resulted in three TMCs that are ready to implement various weather information integration strategies, as follows:

1. Kansas City Scout – newly assembled weather information integrated into their ATMS to alert operators and provide them with relevant weather information to make operational decisions.
2. Wyoming Statewide TMC – weather information integrated into variable speed limit system to better inform operators to assign appropriate speed limits depending on road weather conditions.
3. Colorado Springs TMC – weather information integrated in TMC to better assign traffic signal timing during snow and ice conditions. Currently conducting a pilot test on one signal grid area within the city involving a major arterial and feeder routes.

In addition, other TMCs may be advancing their weather information integration capabilities. This group may include TMCs that were originally contacted and whose experiences formed the basis for the current strategies in the Guide and those that have recently downloaded the Guide from the FHWA website.

This recommendation proposes to: 1) continue supporting the three TMCs listed above in implementing their respective weather information integration strategies and conducting an evaluation to identify and document evidence of weather integration outcomes and benefits, and 2) investigate other TMCs that also may be actively enhancing their weather information integration capabilities and assist them in evaluating and documenting their experiences. Specifically, this effort would:

- Assist Kansas City Scout to complete their evaluation plan (based on their most current implementation approach) and execute the plan by conducting an evaluation of their new weather integration system. This effort would provide quantifiable measures of the benefits of integrating weather information into a sophisticated ATMS system to alert operators, provide them with enhanced road weather information, and support their decision making.
- Work with the Wyoming Statewide TMC to prepare an evaluation plan (based on their weather integration implementation) and execute the plan by conducting an evaluation of their weather integration efforts. This activity would work closely with the University of Wyoming that is currently evaluating the variable speed limit system on I-80 in southern Wyoming. This effort would provide quantifiable measures of outcome benefits of integrating road weather information into their TMC to better inform operators and possibly automate their I-80 variable speed limit system.
- Assist the Colorado Springs TMC to complete the evaluation plan for their pilot test and execute the plan by conducting an evaluation of the weather responsive signal timing plans. This effort would provide quantifiable benefits of implementing snow and ice conditions signal timing plans.
- Investigate other TMCs that may be enhancing, or desiring to enhance, the integration of weather information in their TMCs. This activity would include contacting those that are known to have downloaded the Guide and determine their use of the Guide. This would also include contacting the original ten TMCs that formed the basis for the current state-of-the-practice in weather information integration. A short list of TMCs believed to have recently expanded their capabilities or planning to do so in the near future would be prepared.
- Assist the above short list of TMCs to complete an evaluation plan and then carry out an evaluation of their TMC weather information integration implementation. This effort would add to the benefits database developed by working with the first three TMCs as described above.
- Summarize the benefits realized through these proposed evaluations into a report and database that can be used by the RWMP and others to promote weather integration.

Outcome: The outcome of this recommendation will be a set of documented benefits (a report and database) attributable to the implementation of specific weather information integration strategies that could be used to promote and sustain the RWMP's weather integration in traffic operations initiative.

8.3 Recommendation 3: Assure Currency and Relevance of Weather Integration

Objective: In order to encourage and assure the adoption of weather information integration strategies in TMC operations, the RWMP must facilitate the on-going evolution of integration strategies to "keep pace" with rapid technology and programmatic developments of direct interest to TMC traffic operations and management.

Rationale: Weather information integration as an RWMP initiative is unlikely to become routinely accepted and implemented in the nation's TMCs if it is presented as a concept essentially detached from the major transportation program initiatives and new information management technologies being introduced today and in the future. While TMCs for the most part understand the connections between road weather conditions, and system performance, traveler safety and mobility, they also need to understand how weather integration strategies fit in with and can be supported by the new technologies being introduced in state DOTs. Failure to maintain and promote weather integration that is fully consistent and integrated with the latest technologies and program initiatives can lead to reduced interest, adoption and deployment of potentially beneficial weather integration strategies.

Approach: An initial challenge is to clearly characterize how the USDOT's transportation initiatives can benefit from, as well as support, weather integration in TMC operations. A recommended approach is to prepare a white paper on "Relevance of Weather Information Integration to TMCs." This white paper would seek to incorporate the following elements:

- Describe advances in ATMS hardware and software that can accept and support improved processing and management of weather information. Clarify the data formats that optimize the utility of weather information, and describe the outputs that can most benefit traffic operations. Provide examples of effective uses of weather information in TMC operational settings utilizing current ATMS computer structures.
- Identify and describe the major current transportation program initiatives and how weather information serves as inputs to those programs along with how the programs can encourage and benefit weather integration strategies. The role of weather information integration needs to be examined in three major emerging programs – Active Transportation Demand Management (ATDM), Integrated Corridor Management (ICM), and the Connected Vehicle initiative. In each of these programs, RWMP should encourage increased understanding and use of weather information. For example, future ICM initiatives around the country should consider a weather-responsive scenario and the ATDM program could focus on linking active traffic management & travel demand management during adverse weather. The RWMP has already started engaging the Connected Vehicle community in considering vehicles not only as mobile observation platforms but also as receivers of customized spot-specific road weather information.
- The RWMP has stressed the importance and value of encouraging TMCs to become more proactive with regard to weather information and its integration into operations. However, TMCs have difficulty visualizing what it means to be proactive with weather. Traditionally, TMC operations has focused on traffic performance, and attended to weather only after they observe evidence that weather has affected traffic adversely. Does being more proactive suggest anything more than increasing preparedness for dealing with on-coming weather? Most TMCs are not willing or prepared to notify travelers about weather before it strikes or before there is evidence that it is impacting traffic flow or safety. The white paper should clarify in practical terms, using real examples, what it means to be proactive with regard to weather integration and how being more proactive offers benefits.
- This approach overlaps with the recommendation related to updating the tools used to support TMCs working through the self-evaluation, planning and implementation process for weather integration, and the recommendation related to more thoroughly understanding and communicating the benefits of weather integration. The weather integration initiative must be kept responsive and relevant to TMC operational needs.

Outcome: This recommendation emphasizes the importance of staying flexible and adjusting weather information integration strategies and rationale to keep current and relevant. Outcomes would include clear, practical examples of how weather integration fits in with the current and projected major transportation program initiatives (both supporting and benefiting from them). The recommended white paper will support further marketing and promotion of weather integration among TMCs by further clarifying its operational benefits.

8.4 Recommendation 4: Refine Self-Evaluation Process and Improve Tool

Objective: In order for TMCs to evaluate their current and future potential level of weather integration, they require a tool that is both easy to use and is up-to-date with the most current advances in weather integration strategies.

Rationale: The results of working with several TMCs (documented in this report) suggests that the current weather integration self-evaluation and planning guide (the tool) was extremely useful to assist them with identification of potential weather integration strategies based on their stated needs. However, they did offer suggestions for improvements to the guide to enhance usability, provide better interactive features, and improve the linkages between the needs, strategies and recommendations. Also, the TMCs had difficulty transitioning from selecting weather integration strategies to developing an integration/implementation plan – the consultant team assisted each of them to complete this task. Additionally, the consultant team noticed that all the TMCs got stuck in Section 5 of the guide not knowing how to proceed – they needed assistance at that point to complete the process. Their primary concern was how to select and prioritize the recommended strategies. It is essential that the RWMP's weather integration self-evaluation and planning process, and the related tool, be understandable, easy to use, technically sound and up-to-date with the most current information.

Approach: This recommendation focuses on refining and updating the weather integration self-evaluation and planning process, improving the tool's usability, and incorporating the most current technological advances in both (the process and the tool). Specifically, this effort will:

- Review and update the need statements to be more reflective of TMC desires to be more proactive with their responses to road weather conditions.
- Research and update the road weather integration strategies to reflect the most advanced practices being promoted by USDOT and implemented by state DOTs and TMCs. These incorporate the latest communication, programmatic and technological advances, reflect today's best practices, and support new program initiatives such as Connected Vehicles, ICM and ATDM. This may involve revising the weather integration strategy definitions and levels.
- Improve the matrix of needs to weather integration strategies based on the findings of the first two bullets.
- Review the complete weather integration self-evaluation and planning process as appropriate to possibly enhance and/or add elements such as how to describe a more iterative process, improve upon the implementation planning approach, and adding guidance on evaluating the benefits of the selected strategies for implementation.
- Revise the tool based on the above outcomes and host the tool on a new more flexible platform (an Internet-based product) to address some of the input received by the TMCs to improve its usability. The current Microsoft Access based tool has limitations that can not be overcome using this platform.

Outcome: The outcome of this recommendation will be a technically and programmatically up-to-date weather integration self-evaluation and planning process, and a more usable tool that TMCs can use to investigate and implement possible road weather integration strategies to improve their operations during inclement weather conditions.

8.5 Conclusion

This report has demonstrated significant progress toward the implementation of advanced levels of weather information integration strategies among many of the TMCs that participated in this study. They have important accomplishments to show for their efforts. The future holds great opportunity to extend the benefits of weather integration to many more TMCs across the country that face weather challenges in their daily traffic operations. This study presented some lessons from the experience of the past six years of this integration program that highlight the importance of strong self-motivation within TMCs to engage a team composed of operations, maintenance and related agency representatives in weather integration within an environment of constrained resources. The four recommendations presented are directed toward sustaining and enhancing the weather integration program, building additional evidence supporting the benefits of integration, and assuring that the support and tools available to TMCs to help them are effective and up-to-date.

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APPENDIX A. List of Acronyms

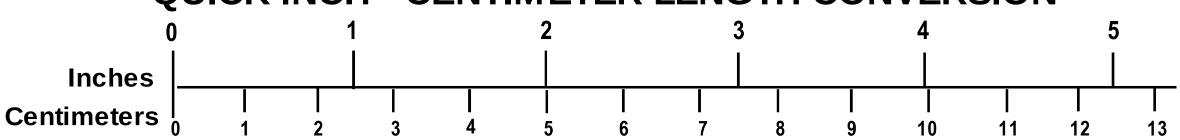
AADT	**Average Annual Daily Traffic**
AASHTO	**American Association of State Highway and Transportation Officials**
ATDM	**Active Transportation Demand Management**
ATMS	**Advanced Traffic Management System**
AVL	**Automated Vehicle Location**
CARS	**Condition Acquisition and Reporting System**
CCTV	**Closed Circuit Television**
CDOT	**Colorado Department of Transportation**
Clarus	**FHWA Road Weather Information Database**
CO	**Colorado**
CSP	**Colorado State Patrol**
CSPD	**Colorado Springs Police Department**
CSTMC	**Colorado Springs Traffic Management Center**
CTMC	**Colorado Statewide Transportation Management Center**
DMS	**Dynamic Message Sign**
DOT	**Department of Transportation**
DOTD	**Department of Transportation and Development**
DUI	**Driving Under Influence**
ECAR	**Enhanced Citizen-Assisted Reporting**
EOC	**Emergency Operations Center**
FHWA	**Federal Highway Administration**
GIS	**Geographic Information System**
Guide	**Weather Information Integration Self-Evaluation Guide**
HAR	**Highway Advisory Radio**
ICM	**Integrated Corridor Management**
ITE	**Institute of Transportation Engineers**
ITS	**Intelligent Transportation System**
KDOT	**Kansas Department of Transportation**
LOS	**Level of Service**
LSU	**Louisiana State University**
MA/ER	**Motorist Assist/Emergency Response**

MAP	**Motorist Assistance Patrol**
MDC	**Mobile Data Computer**
MoDOT	**Missouri Department of Transportation**
MOU	**Memorandum of Understanding**
NDFD	**National Digital Forecast Database**
NDOR	**Nebraska Department of Roads**
NOAA	**National Oceanic and Atmospheric Administration**
NWS	**National Weather Service**
O&M	**Operations and Maintenance**
POC	**Point of Contact**
RTMC	**Regional Transportation Management Center**
RWIS	**Road Weather Information System**
RWMP	**Road Weather Management Program**
SALECS	**State Law Enforcement Communications Systems**
SQL	**Structured Query Language**
TCS	**Traffic Control System**
TMC	**Transportation Management Center or Traffic Management Center**
USAFA	**U.S. Air Force Academy**
USDOT	**U.S. Department of Transportation**
VD	**Vehicle Detection**
VDS	**Vehicle Detection Stations**
VMS	**Variable Message Sign**
VSL	**Variable Speed Limit**
WRTM	**Weather Responsive Traffic Management**
WSDOT	**Washington State Department of Transportation**
WYDOT	**Wyoming Department of Transportation**
Wx	**Weather**

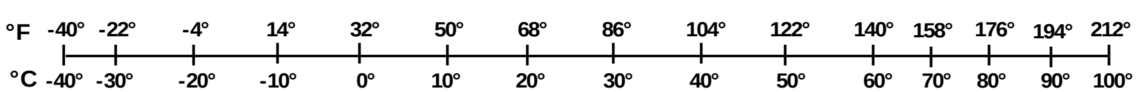
APPENDIX B. Metric/English Conversion Factors

ENGLISH TO METRIC	METRIC TO ENGLISH
LENGTH (APPROXIMATE)	**LENGTH (APPROXIMATE)**
1 inch (in) = 2.5 centimeters (cm)	1 millimeter (mm) = 0.04 inch (in)
1 foot (ft) = 30 centimeters (cm)	1 centimeter (cm) = 0.4 inch (in)
1 yard (yd) = 0.9 meter (m)	1 meter (m) = 3.3 feet (ft)
1 mile (mi) = 1.6 kilometers (km)	1 meter (m) = 1.1 yards (yd)
	1 kilometer (km) = 0.6 mile (mi)
AREA (APPROXIMATE)	**AREA (APPROXIMATE)**
1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)	1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)	1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)	1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)	10,000 square meters (m^2) = 1 hectare (ha) = 2.5 acres
1 acre = 0.4 hectare (he) = 4,000 square meters (m^2)	
MASS - WEIGHT (APPROXIMATE)	**MASS - WEIGHT (APPROXIMATE)**
1 ounce (oz) = 28 grams (gm)	1 gram (gm) = 0.036 ounce (oz)
1 pound (lb) = 0.45 kilogram (kg)	1 kilogram (kg) = 2.2 pounds (lb)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)	1 tonne (t) = 1,000 kilograms (kg)
	= 1.1 short tons
VOLUME (APPROXIMATE)	**VOLUME (APPROXIMATE)**
1 teaspoon (tsp) = 5 milliliters (ml)	1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 tablespoon (tbsp) = 15 milliliters (ml)	1 liter (l) = 2.1 pints (pt)
1 fluid ounce (fl oz) = 30 milliliters (ml)	1 liter (l) = 1.06 quarts (qt)
1 cup (c) = 0.24 liter (l)	1 liter (l) = 0.26 gallon (gal)
1 pint (pt) = 0.47 liter (l)	
1 quart (qt) = 0.96 liter (l)	
1 gallon (gal) = 3.8 liters (l)	
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)	1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)	1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)
TEMPERATURE (EXACT)	**TEMPERATURE (EXACT)**
[(x-32)(5/9)] °F = y °C	[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSION



For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

APPENDIX C.
TMC Weather Information Integration Plans

- Kansas City Scout
- Louisiana Statewide and Regional TMCs
- Colorado Springs
- Wyoming Statewide

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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