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Integrating Weather in TMC Operations

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16. Abstract This report presents the results of a study of the integration of weather information into Transportation Management Centers (TMCs). Based on an earlier report that examined the nature and extent of weather integration experience across the country and identified best practices, this study examines the efforts of two selected TMC to evaluate their weather integration needs and develop a detailed weather integration plan. The project team selected these TMCs based on their motivation to participate and worked closely with them as they executed a self-evaluation process developed as part of this project. A Self-Evaluation Guide was designed and implemented in an electronic database format to assist the TMCs in working through a series of steps that identified their weather conditions, the impacts weather has on their operations, their current level of weather integration in the TMC, and their expressed needs for enhanced integration. The Self-Evaluation Guide then offered a set of possible integration strategies that the TMC could select and incorporate into their weather integration plan that would serve to meet their indicated integration aspirations. The study reviewed relevant literature on weather integration, incorporated insights from the review into the development of the Self-Evaluation Guide, and identified lessons learned from the experiences of working with the two TMCs. Based on this experience the Self-Evaluation Guide was further refined several times, and a set of recommendations are offered for a possible future course of action of the Federal Highway Administration's Road Weather Management Program.			
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List of Acronyms

AASHTO	American Association of State Highway and Transportation Officials
AMS	American Meteorological Association
ATIS	Advanced Traveler Information Systems
ATMS	Advanced Traffic Management System
DMS	Dynamic Message Sign
DOT	Department of Transportation
CCTV	Closed Circuit Television
EOC	Emergency Operations Center
ESS	Environmental Sensor Station
FHWA	Federal Highway Administration
HAR	Highway Advisory Radio
HCRS	Highway Condition Reporting System
HOV	High Occupancy Vehicle
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
MDSS	Maintenance Decision Support System
NHI	National Highway Institute
NWS	National Weather Service
O&M	Operations and Maintenance
RTMC	Regional Transportation Management Center
RWIS	Road Weather Information System
RWMP	Road Weather Management Program
RWRI	Road Weather Resource Identification
SA	Self-Assessment
STOC	State-wide Transportation Operations Center
TIM	Traffic Incident Management
TMC	Transportation Management Center
TMDSS	Traffic Management Decision Support System
TOC	Transportation Operations Center
TRB	Transportation Research Board
USDOT	U.S. Department of Transportation
VMS	Variable Message Sign
WECCP	Winter Event Communications/Coordination Plan
WEERP	Winter Event Emergency Response Plan
WZ SA	Work Zone Self-Assessment

1 Introduction

1.1 Background

The Federal Highway Administration's (FHWA) Road Weather Management Program (RWMP) has established a research agenda, referred to as their programmatic 'road map,' that identifies the integration of weather information into the operations of Transportation Management Centers (TMCs) across the country as a key objective. Integrating weather information supports the capability of state and local transportation agencies to better manage their traffic, dispatch maintenance crews and respond appropriately and in a timely way to weather-induced problems affecting the transportation system. Well-integrated weather information allows TMC operators to make effective and timely management and operational decisions based on quality information related to weather forecasts, the anticipated timing and intensity of weather events, the interaction of weather conditions with the road surface, and the type and availability of appropriate transportation management devices and systems. Integrated weather information positions a TMC to be proactive rather than reactive with regard to the operations and maintenance of their transportation infrastructure, and supports a set of activities that can be characterized as advisory, treatment and control.

The objectives of this study are to prepare a detailed self-evaluation guide that will assist TMCs in identifying appropriate weather integration strategies, given their current level of weather integration and their desire for additional operational capabilities through enhanced weather integration. This project sought to assist two TMCs in developing a weather integration plan based on integration strategies identified through their self-evaluation. These two TMCs were selected to work with and help refine the self-evaluation guide and integration planning process.

The intended next steps along the RWMP 'road map' will include selecting additional TMCs to work with the guide and implement weather integration enhancements into their TMC operations. More specific suggestions are presented in a set of sequenced recommendations described in Chapter 6.

1.2 Prior Integration Study

The FHWA RWMP, in partnership with the FHWA Emergency Transportation Operations Program, completed a survey and analysis of how weather and emergency information are being integrated into the operations of TMCs throughout the country. The goal of this study was to identify best practices and develop guidance to enhance the operations of TMCs during inclement weather and emergency situations. The final report from this study[1] summarized how weather and emergency information and decision-support systems are being integrated in thirty eight TMCs around the US, and explores strategies for applying practical, effective concepts and methods of integration in the future. The report discussed a framework for integration, the current state of the practice, potential benefits, and challenges associated with integrating weather and emergency information in TMCs. This report also offered a number of

[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://ops.fhwa.dot.gov/weather/resources/publications/tcmintegration/index.htm

recommendations for how weather integration could be encouraged and supported. One of these recommendations has led to the work that is discussed in this report; namely, a recommendation that TMCs "should conduct a self-evaluation to help identify the most effective integration solutions and guide their deployment." A comprehensive self-evaluation process is described in this report, and the suggested integration solutions that emerge from this self-evaluation lead directly to the development of a weather integration plan that the TMC can follow to achieve increased integration.

1.3 Expected Benefits of Weather Integration

Working through the self-evaluation process will help TMCs assess their needs for weather integration, offer specific candidate integration strategies that they can implement, and clarify the benefits they could expect to derive from enhanced weather integration. Some of the expected benefits from enhance integration include the following:

- Well-informed operational staff who understand the effects of weather events on road conditions and transportation system performance.
- Timely operational weather-related decision making.
- Operational understanding of available weather integration tools and how to use them effectively in a TMC.
- The ability to effectively utilize forecast weather events and prepare proactively before serious problems arise.
- The recognition of the value of a weather perspective imbedded in the TMC concept of operations and accepted as the preferred way of conducting the functions of the TMC.

A long-run objective and benefit of having a TMC work through this process from self-evaluation to plan development and implementation of integration strategies, is expected to be improved operational performance in responding to traffic conditions influenced by weather events. Ultimately, the goal is for the TMC managers and operators to fully embrace a culture that supports the use of new technologies and strategies for dealing with inclement weather. Thus, technical changes are expected to be incorporated along with institutional and organizational culture changes. The goal is for TMC operators to recognize the importance of road weather in their operations, to understand and use the tools that are available to assist them in better managing weather-influenced events, and to proactively seek out and access other resources in support of more effectively interpreting weather phenomena in the context of their transportation mission.

As a generalization, weather integration is at a relatively low level in most TMCs across the country. In many it is non-existent at this time, even though weather, in some form, is affecting safety and mobility in every state. To address this deficiency, the goals of the RWMP include:

- Maximize the use and availability of road weather information and technologies.
- Expand road weather research and development.
- Promote technology transfer of effective road weather scientific and technological advances.

The RWMP's 'roadmap' of desired growth in road weather utilization is structured to meet these goals, and the underlying assumption is that the benefits of increased weather integration in TMC operations will be substantial.

2 Literature Review

Prior to development of a self-evaluation guide, it was important to understand the nature of weather impacts on capacity and speed reductions, impacts on safety and, impacts on institutional coordination, to ensure that the self-evaluation and the integration solutions address the right concerns.

The literature review focused on developing the framework for what the self-evaluation guide should look like, and review prior weather integration work. The review brought to light the following:

- Recent relevant literature for road weather management and research findings as they pertain to weather integration.
- Implications of the effects of weather event characteristics on traffic operations and TMC functions.
- Examples of weather integration solutions used in TMCs.
- Examples of self-evaluation guides in current use.

The next two sections discuss selected findings from the review.

2.1 Weather Integration State of the Practice

The potential to reduce or avoid the impacts of weather on transportation system operations provides the rationale for improved weather integration within TMCs. The process by which this occurs is greatly facilitated through both the identification of concepts, or ideas, by which effective and optimal integration may occur and the methods that show how the concepts can be realized and effectively implemented. The concepts that provide the most effective pathway for integration for a particular TMC will depend upon the needs and issues central to a specific transportation network. However, the success of any weather integration effort must begin with solid concepts that describe what integration looks like in a particular TMC application.

The report titled *Integration of Emergency and Weather Elements into Transportation Management Centers*[2] examined the level of integration at TMC sites in terms of the extensiveness of implementation along five dimensions, as follows:

- Operational Integration
- Physical Integration
- Technical Integration
- Procedural Integration
- Institutional Integration

The report identified concepts and strategies for weather-responsive traffic operations and incorporates the three mitigation strategies: *advisory, control, and treatment*. This report developed a framework for weather integration. State-of-the-practice and the best practices are

[2] Cluett. C. et al.

also identified in the report (pages 59-60) as well as a compendium of integration strategies across the various dimensions for TMCs (pages 61-67). While the concepts and strategies presented in the final report were expected to be the foundation of the weather integration solutions presented in the guidance developed for this task, additional best practices in road weather management were identified and reviewed for incorporation into the solution set. Some of the findings are described below:

- In North Carolina, the City of Charlotte Department of Transportation (DOT) manages the operation of 615 traffic signals with a computerized control system. In the central business district weather-related signal timing plans are utilized at 149 signals to reduce traffic speeds during severe weather conditions. System operators assess traffic and weather conditions by viewing Closed Circuit Television (CCTV) video images and receiving weather forecasts. Forecast data are available through radio and television broadcasts, the National Weather Service (NWS) website, and a private weather service vendor. When heavy rain, snow, or icy conditions are observed operators access the signal computer and manually implement weather-related timing plans. To slow the progression speed of traffic these signal timing plans increase the cycle length – which is typically 90 seconds – while offsets and splits remain the same. During off-peak periods operators may also select peak period timing patterns, which are designed for lower traffic speeds. Travel speeds decrease by five to ten miles per hour (mph) when weather-related signal timing is utilized.[3]

- In Houston, co-located agencies manage flooding and weather events at TranStar. Traffic and emergency managers use central computers to monitor CCTV video, Environmental Sensor Station (ESS) data, and information from the NWS and private vendors (e.g., radar, river forecasts). When established threshold criteria for weather conditions and traffic impacts are met, the Emergency Operations Center (EOC) in the TranStar facility is activated and computers send alarms to maintenance managers (via email and pager). Managers from each agency coordinate to plan appropriate responses and to warn motorists. The transit authority uses ESS data to manage operations in High Occupancy Vehicle (HOV) lanes which are prone to icing and flooding. If warranted, maintenance personnel will erect barricades to close flooded roadways.[4]

- The Washington State Department of Transportation employs variable speed limit message signs on a 40-mile (64-kilometer) segment of I-90 to improve roadway safety in the presence of fog, snow, and ice. A University of Washington study found that although speed variance increased slightly, speed management reduced average speed by up to 13 percent.[5]

- In Arizona, a variety of independent applications to monitor roadway conditions and activities across the state include traffic counts, weather data, signal timing, Variable

[3] Goodwin, L.C. (2003). *Best Practices for Road Weather Management, Version 2.0* (FHWA-OP-03-081). Washington, DC: Federal Highway Administration. Available at http://ops.fhwa.dot.gov/weather/best_practices/CaseStudiesFINALv2-RPT.pdf
[4] Ibid.
[5] Ibid.

Message Sign (VMS) advisory messages, video signals, and statewide Highway Condition Reporting System (HCRS) events that were consolidated to a "single-screen" view. The implementation of this capability involved the development of software interfaces with device driver applications via the Internet and intranet. This resulted in the centralization and improved availability and archiving of traffic data derived from the associated Intelligent Transportation Systems (ITS) field devices, as well as data from the Advanced Traveler Information System (ATIS) via the HCRS. This outcome improved the real-time aspect of the operational management of the state highway system.[6]

- The New Jersey Turnpike Authority traffic and emergency management personnel in the Transportation Operations Center (TOC) monitor environmental data to determine when speed limits should be lowered. When speed reductions are warranted, sign assemblies are manually activated to post a decrease in speed limits in five-mph increments from 50, 55, or 65 mph to 30 mph depending on prevailing conditions. System operators may also disseminate regulatory and warning messages via Dynamic Message Signs (DMS) and Highway Advisory Radio (HAR). State police officers enforce the lower speed limits by issuing summonses to drivers exceeding the posted limit. When the vehicle detection and Road Weather Information System (RWIS) subsystems indicate that traffic and weather conditions have returned to normal, the original speed limits are restored. This control strategy effectively decreases traffic speeds in adverse conditions. Speed management and traveler information dissemination have improved safety by reducing the frequency and severity of weather-related crashes.[7]

- A road management system has been implemented in Japan to support decisions concerning when to mobilize snow removal organizations and perform snow removal work, and also to provide information seamlessly to road users.[8] Figure 1, recreated from the report, shows the road management support system flow – the procedure followed to convert road weather data to forecasting traveling speed and forecasting travel time, plus the procedures road managers will follow to utilize these forecasts and procedures for the use of this information by road users.

- The Finnish Road Administration is planning the integration of road weather information and traffic detection for traffic control for two cases in Finland.[9] For a high-risk three-way intersection with ice and snow events, road weather information has been planned for use with traffic information so that the speed limit values of implemented variable speed limit signs are appropriate not only at prevailing traffic conditions but also at dominant road weather conditions. For a stretch of freeway, weather-related parameters (including wind speed and direction, air temperatures, road surface and road structure, humidity, intensity and state of precipitation, visibility, state of the road surface and state

[6] Ibid.
[7] Ibid.
[8] Yamada, T. and Maruyama, T. (2002). Construction of a road management support system using information forecast. *Proceedings of the 11th International Road Weather Conference*. Sapporo, Japan: SIRWEC. Available at http://www.sirwec.org/en/index.php?page=../conferences/sapporo2002
[9] Portaankorva, P. (2002). Road Weather and Traffic Data in Traffic Management. *Proceedings of the 11th International Road Weather Conference*. Sapporo, Japan: SIRWEC. Available at http://www.sirwec.org/en/index.php?page=../conferences/sapporo2002

of the bridge deck over the river) are used in conjunction with real-time traffic information (like traffic volume, queue length and headway information and the speed of traffic) to automatically adjust speed limits.

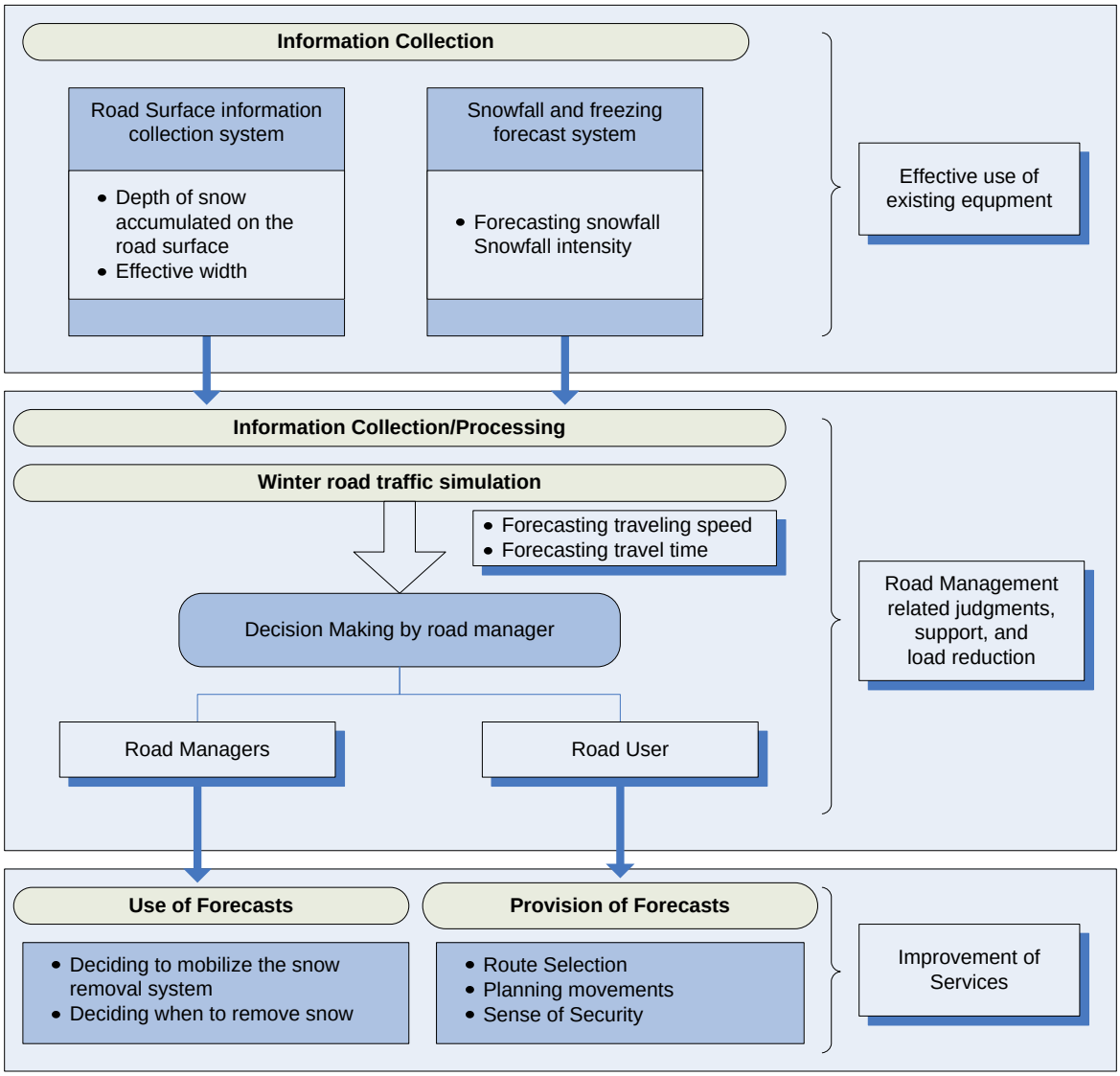


Figure 1. Road Management System

The National ITS architecture framework includes several services or market packages that are directly relevant to weather integration such as Road Weather Data Collection, Weather Information Processing and Distribution; Winter Maintenance; Maintenance and Construction Vehicle Tracking; Roadway Automated Treatment; and Maintenance and Construction Activity Coordination. These market packages illustrate the coordination and desired information exchanges between traffic management, maintenance management, field devices, and weather information service providers.[10]

[10] U.S. Department of Transportation (2007, April). National ITS Architecture, Version 6.0. Available at www.iteris.com/itsarch.

It is also important to ensure that the "weather-integration" plan developed as part of this project addresses the following four critical elements identified in the *weather-responsive traffic management concept of operations*:[11]

1. Basic operational objectives – what are the operational goals of the TMC that drive the day-to-day activities of traffic managers and constitute their core mission?
2. Information gathering and impact assessment – When weather events occur or are predicted to occur, traffic managers need to gather information on the event and assess its impacts.
3. Operational strategies – During a significant weather event, traffic managers implement a series of specific operational strategies that are designed to meet the basic operational objectives identified above.
4. Transportation outcomes – Operational strategies are designed to achieve specific transportation outcomes that can be clearly identified and measured.

2.2 Self-Evaluation Structure and Formats

Self-evaluation is a familiar theme in the transportation community, especially in the ITS integration area. An important element of the ITS Integration Program, managed by the U.S. Department of Transportation (USDOT) ITS Joint Program Office (JPO), is to assess how well the selected projects perform at meeting program goals and to share their experiences with others. However, the self-evaluation approach and framework for the ITS Integration Program is significantly different from what is needed for this project.

For this project, the self-evaluation needs to assess the current situation, the future vision, and identify methods to reach a desired state of operations. In other words, the self-evaluation needs to be introspective and prescriptive. Fewer examples exist in the TMCs or the general ITS arena of assessing entire programs to identify gaps, needs and options.

In recent years, while not specific to TMCs, several such assessments, evaluations, or report cards have been created by FHWA and other agencies or organizations in the areas of incident management, work zones, statewide traffic operations, emergency transportation operations, and traffic signal operations. This section describes the various structures, the assessment methodologies and techniques used in these evaluations. Most of the self-evaluations are structured as a series of questions to be answered by a group of stakeholders identified by the agency conducting the self-evaluation. These evaluations are usually accompanied by a scoring guide and explanations of the questions. The following describes the important characteristics of several of the more recent self-evaluations developed by FHWA and other agencies.

[11] Cambridge Systematics. (2003). *Weather-Responsive Traffic Management Concept of Operations (Draft)*. Washington, DC: Federal Highway Administration. Available at http://ops.fhwa.dot.gov/Weather/best_practices/WeatherConOps0103.pdf

- *The Traffic Incident Management Self-Assessment Guide*[12] - The Traffic Incident Management (TIM) Self-Assessment (SA) is a tool to be used by state and regional program managers to assess their achievement of a successful multi-agency program to manage traffic incidents effectively and safely. The TIM SA consists of a series of questions, grouped under three sections: program and institutional issues, operational issues, communications, and technology issues. These questions are designed to allow those with traffic incident management responsibilities to evaluate program performance in specific organizational and procedural categories. Conducted as a *facilitated group exercise,* the TIM SA provides a format for discussion among the group members aimed at reaching a consensus on various aspects of a traffic incident management program.

  An important aspect of the SA is the level of guidance provided to the agency performing the self-assessment. The SA spreadsheet is accompanied by a guide that describes the key pieces of information essential to ensure a consistent self-evaluation by different agencies. The guide includes:

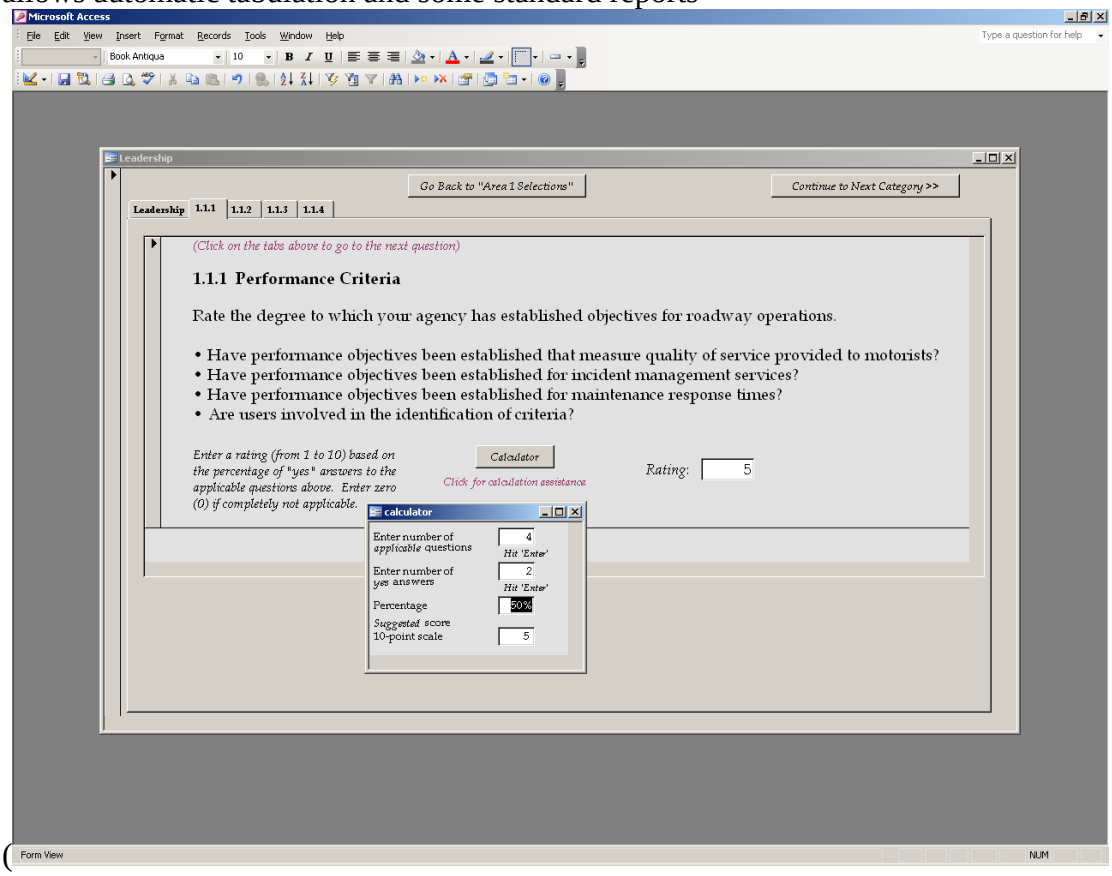
  - Background and Purpose
  - Facilitator's Guide
  - Scoring Guidance –offers specific guidance for each question in the self-assessment to assist those assessing their programs to better evaluate their program performance.

- *The Work Zone Mobility and Safety Self-Assessment (WZ SA)*[13] tool consists of a set of questions designed to assist those with work zone management responsibilities in assessing their programs, procedures, and practices against many of the good work zone practices in use today. The WZ SA consists of a guide and a score sheet. The Guide describes how to conduct and score the WZ SA and delineates and explains the WZ SA questions.

- *The Roadway Operations Internal Self-Assessment tool*[14] has been designed to help agencies assess their roadway operations and system management performance. Its goal is to help an agency evaluate its operational effectiveness, both in terms of its internal processes and the degree to which it serves its customers. The SA is structured into two major areas – organizational and business results. Each area is divided into categories and questions under each area. The SA tool has been created as an Access database that

[12]Federal Highway Administration. (2004). *Traffic Incident Management (TIM) Self-Assessment Guide*. Available at http://www.iacptechnology.org/IncidentManagement/TrafficIncidentMgmtAssesGuide.pdf
[13] Federal Highway Administration. (2004). *Work Zone Self-Assessment*. Available at: http://ops.fhwa.dot.gov/wz/decision_support/self-assess.htm
[14] FHWA. 2004. *Roadway Operations Self-Assessment: Version 2.0.* Prepared by Cambridge Systematics and PB Farradyne. (April).

allows automatic tabulation and some standard reports



(

- Figure 2). An interesting feature is the ability of the user to select weights ranging from not applicable (0) to very important (10) for each question and categories (e.g. leadership, planning) under each area. While this weighting allows an agency to pick and choose questions of relevance to their self-assessment, it makes comparisons of final scores between agencies meaningless. In other words, the SA will not necessarily provide a basis for comparison with other agencies, but will instead highlight areas in which improvements can be made.

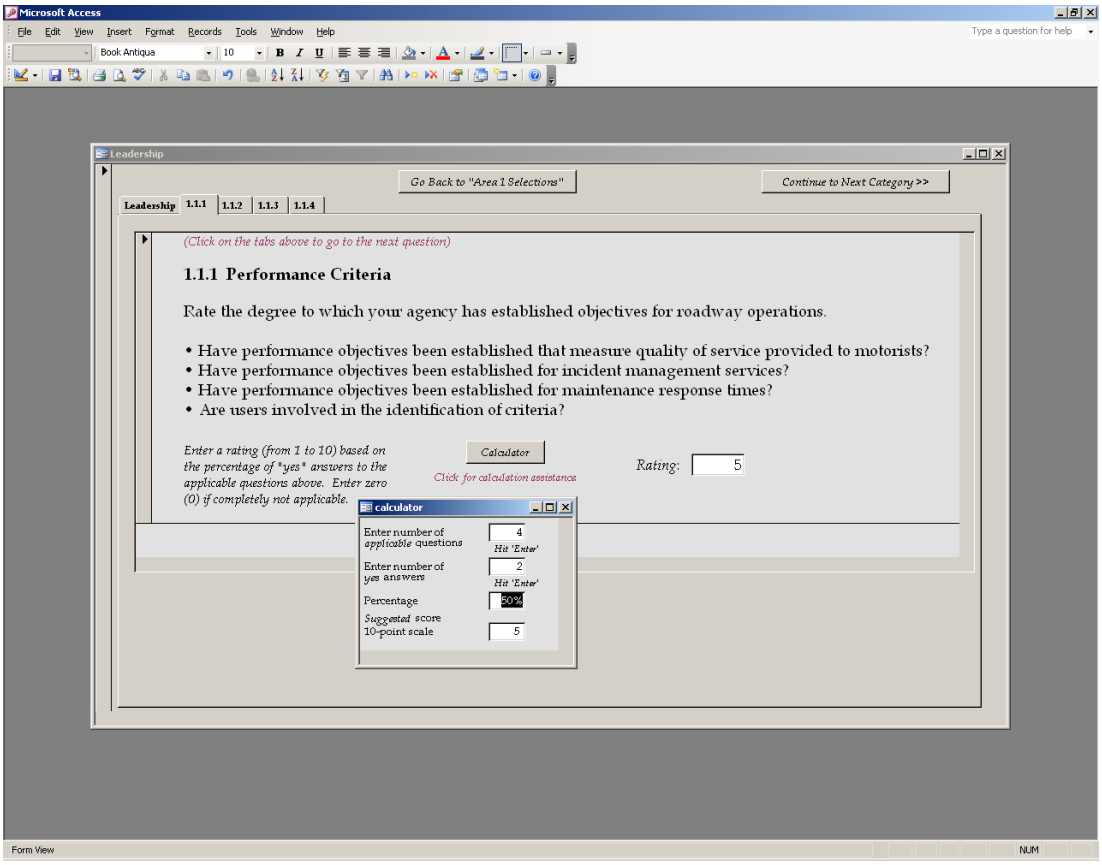


Figure 2. Roadway Operations Self-Assessment Database

- *The Traffic Signal Operations Self-Assessment*[15] consists of six sections. Each section contains a number of questions concerning traffic signal operation policies and practices. Respondents are asked to rate the extent to which a particular policy or practice has been adopted by the agency. The self-assessment is designed to describe the benchmark for traffic signal operation practice. Each question is followed by a short description that illustrates outstanding practice (a score of "5"). This provides the agency with a target for improving its traffic signal operation. It is not anticipated that any agency will have a perfect score. The SA is intended to be completed as a group exercise and submitted online.

The four SA tools above are great tools for assessing the efficacy of different transportation management programs or functions. However, the focus is on rating the entire program rather than prescribing solutions to problems. Also, three of the SA models (incident management, work zones and traffic signals) are intended to generate national or aggregate ratings. While the ratings for individual questions and the discussions generated during the group exercise clearly point to gaps and action items, the afore-mentioned SA tools do not clearly prescribe the next steps or the improvement strategies required. These SAs stop at taking an introspective look at a

[15] National Transportation Operations Coalition. (2004). *Traffic Signal Operation Self-Assessment*. Washington, DC: Institute of Transportation Engineers. Available at http://www.ite.org/selfassessment/

program and determining where they stand in comparison to either a perfect program or to other agencies' programs.

A self-assessment methodology that provides guidance based on the results has been developed for emergency transportation operations. The *Guide for Emergency Transportation Operations*[16] is designed to support the development of a formal program for the improved management of traffic incidents, natural disasters, security events, and other emergencies on the highway system. The guidance framework contains two self-assessment areas – Institutions and Leadership, and Operations and Technology.

Under each of the two areas, two related tools for process improvement are provided in the guide:

1. A self-evaluation that allows managers to determine current strengths and weaknesses and thereby focus on the relevant part of the guidance material.
2. General strategies and tactics related to the area.

For the operations and technology area, the guide suggests strategies and tactics at two levels of operation – the base level and advanced level, that are determined based on responses to the self-assessment. The guide also identifies the indicators for advancing to the next level of operations.

In summary, the ETO Guide is the closest example of the type of self-evaluation guide required for this project on integrating weather with TMC operations. Also, similar to ETO, there are no clear "best practices" that are widely accepted or adopted by TMCs for weather integration, and there is new technology available that could support improved weather operations that TMCs might be unaware of leading to missing significant performance improvement opportunities.

The ETO guide illustrates the importance of providing not only an assessment but also education of the new possibilities that is also envisioned in the self-evaluation guide for this project.

A key lesson from the review of the SAs is that all of them recommend using a facilitator-led, consensus building process in conducting the self-evaluation. In fact, the discussion and the consensus-building from the exercise are often claimed as the major achievements of the self-evaluation. Table 1 below describes the Work Zone SA process.

Similarly, the TIM SA Guide includes a Facilitator Guide that provides the facilitator or facilitating agency with enough background and instruction to prepare for the conduct of the assessment, and to ensure its successful completion. Among the issues addressed are:

1. Pre-Meeting Preparations
2. Meeting Facilitation Strategies
3. Post-Meeting Actions

[16] Lockwood, S., O'Laughlin, J., Keever, D., and Weiss, K. (2005). *Surface Transportation Security, Volume 6: Guide for Emergency Transportation Operations* (NCHRP Report 525). Washington, DC: Transportation Research Board. Available at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_525v6.pdf

The TIM SA Guide recommends that while the size of the group will be dictated by the geographic area being assessed, the assessment should be conducted with no less than five participants and no more than 20.

Table 1. Suggestions for the Work Zone Self-Assessment

Assemble a team of participants that is fully versed in planning, designing, constructing, maintaining, and operating the transportation system.
Provide participants with the assessment guide and score sheet in advance so that they may become familiar with the questions and the basis for the questions.
Ask the participants to bring their score sheets and guide with them to the assessment exercise.
Have a designated facilitator for the meeting(s).
Encourage open discussion about each topic area to better understand the participants' responses.
Discuss the final score in each topic section and collect information on any practices, policies, and procedures that are proving successful for the participant in reducing congestion and crashes in work zones.

3 Development of the Self-Evaluation Guide

The literature review yielded important insights that were used in the development of the Self-Evaluation Guide and resulted in a useful integration plan with one TMC using the guide. Some of the relevant findings include:

- **The greatest value of reviewing several self-evaluation guides is in understanding the approach and format used.** In recent years, there has been a focus on developing self-evaluation approaches for TMCs. Existing self-evaluations for incident management, traffic signal operation, and work zones are good models for assessing programs (those are agency-wide, not just for TMCs). However, they do not directly prescribe strategies or solutions to improve the program. Their greatest value to this project is the approach and the format they identify to conduct the self-evaluation. One example of relating the self-evaluation to strategies and guidance has been developed for emergency transportation operations.
- **The prioritization of responses for different categories is likely be more useful for this project than an approach of aggregated weighted rankings of questions.** All self-evaluations have been structured as checklists with accompanying documentation explaining the questions, choices and scoring systems. However, most of the self-evaluations have been set up to generate a rating for the program. Due to the need to generate a single metric, the scoring systems usually involve the aggregation of weighted ratings of questions. As these self-evaluations were reviewed, it was clear that this project need not develop a single metric, and it is more important to be able to prioritize responses in different categories.
- **An electronic format for the self-evaluation is preferred because of its ease of use.** The format of the self-evaluation varies widely from paper-based checklists to web pages, spreadsheets and relational databases. Given the complexity of information, an electronic format as used in the TIM self-assessment is attractive because of its ease of development and use.
- **Self-evaluations are best performed as a facilitated group exercise.** The self-evaluations are typically not intended for a single person to complete. Rather, they are most successful when implemented by a facilitated group of knowledgeable individuals encompassing various aspects of TMC operations. In fact, some of the evaluations mention the discussions and consensus developed as part of this exercise as one of the main benefits of self-evaluation.
- **The precursor study – *Integration of Emergency and Weather Elements into Transportation Management Centers* – offers a detailed source of weather integration strategies and framework**. This study served as the framework for developing the guidelines for weather integration. This included the development of the dimensions of weather integration and strategies for integration that derived from the practices employed by the more advanced TMCs across the country.
- **The "*Best Practices for Road Weather Management*" report provides a valuable source for additional ideas for weather integration**. Examples include variable speed limits, localized motorist warning systems, access control strategies (e.g., road/bridge closures, high-profile vehicle restrictions), weather-related signal timing and incident

detection, integrated traffic and weather data management systems, and advanced traveler information systems. One of the key findings from reviews of the best practices is that the notion of integration, especially the framework suggested by the previous report, is often implied rather than clearly stated. This suggests that the self-evaluation guidelines need to account for the fact that the TMCs are unlikely to be aware of the integration framework (different dimensions, levels of integration).

- **The system engineering process can serve as a model for what elements are required for a good weather integration implementation plan**. The USDOT rule on systems engineering and architecture specifies that the following be included in the project analysis:
  - Identification of portions of the regional ITS architecture being implemented (or if a regional ITS architecture does not exist, the applicable portions of the National ITS architecture).
  - Identification of participating agencies roles and responsibilities.
  - Requirements definitions (this includes both data and functional requirements).
  - Analysis of alternative system configurations and technology options to meet requirements.
  - Procurement options.
  - Identification of applicable ITS standards and testing procedures.
  - Procedures and resources necessary for operations and management of the system.
- **The structure of the "weather integration plan" developed for this project needs to closely mirror the requirements**, especially if the TMCs apply for future federal funding for weather integration.

3.1 Components of the Self-Evaluation Guide[17]

The development of the self-evaluation guide is grounded in an understanding of the purpose and concept for the guide. The self-evaluation guide concept is illustrated in Figure 3. The guide has six main sections, and it is designed to be executed sequentially, beginning with Section 1. Each section builds on the information provided in the previous section; however, each section also provides a meaningful and distinct output. The process to conduct the TMC self-evaluation and develop a plan for weather integration is presented as three major parts in the Self-Evaluation Guide as follows:

I. Self-Evaluation

II. Guidance for Weather Integration

III. Development of a Weather Integration Plan

Parts I and II are considered the Self-Evaluation and Planning processes, while Part III provides information and guidance on developing the integration plan.

[17] Cluett, C., Gopalakrishna, D., Kitchener, F., Balke, K., and Osborne, L. (2008). *Integration of Weather Information in Transportation Management Center Operations: Self-Evaluation and Planning Guide* (Prepared for the Federal Highway Administration, Road Weather Management Program). Seattle, WA: Battelle.

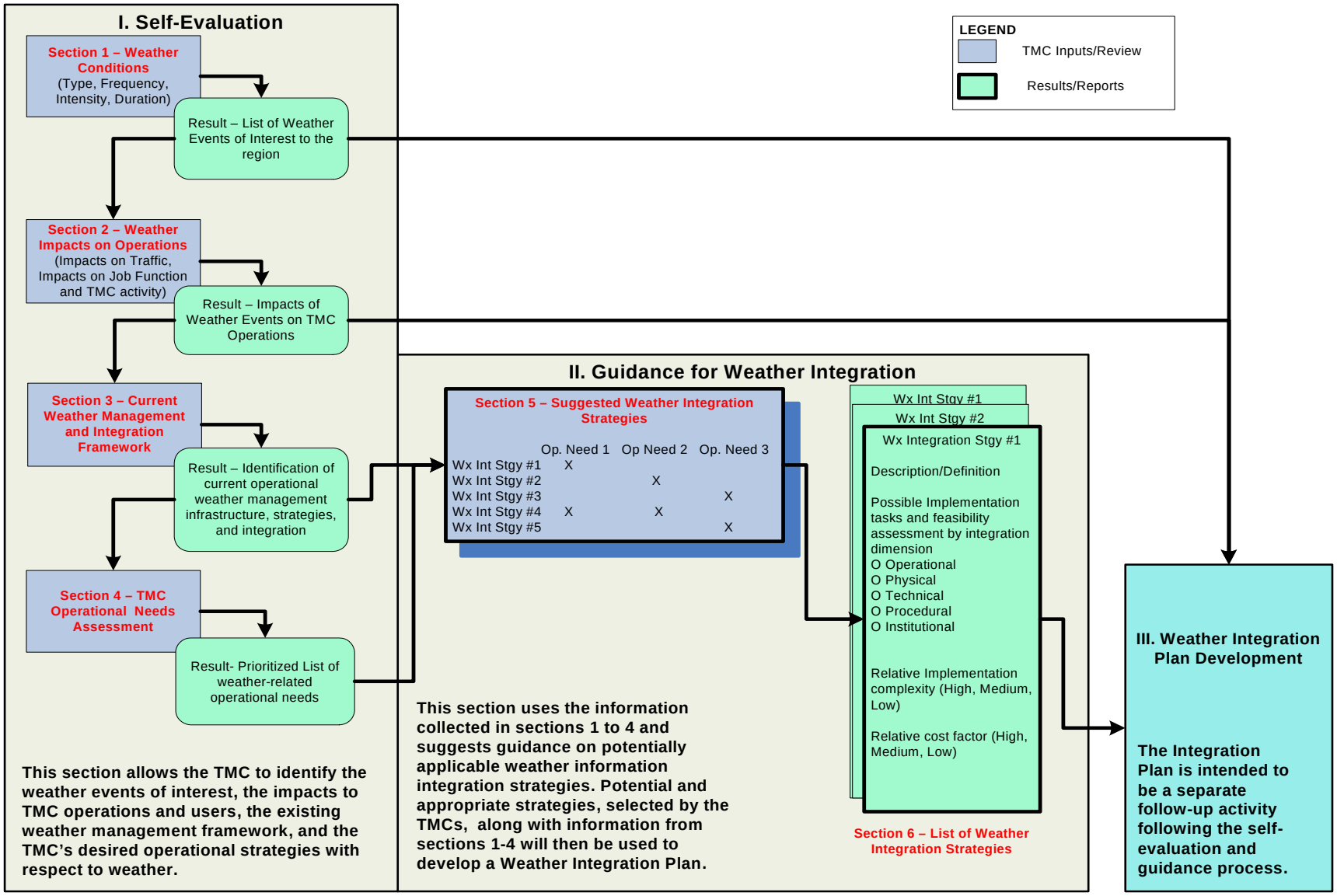


Figure 3. Self-Evaluation and Planning Guide Organization

Part I of the Self-Evaluation Guide consists of four sections with checklists/questions within each. The four sections of the evaluation are:

- Section 1 – Weather conditions. This section identifies the major weather conditions in the region.
- Section 2 – Weather impacts on operations. For the weather conditions identified in section 1, this section determines their impacts on traffic and TMC operations.
- Section 3 – Current management and integration framework. This section defines the current weather information management framework including identifying existing strategies and processes.
- Section 4 – TMC operational needs for weather integration.

Part II of the Self-Evaluation Guide consists of two sections:

- Section 5 – Links the weather integration strategies with high priority operational needs and provides a process for identifying appropriate strategies for the region.
- Section 6 – This section provides several reports including further explanation and detail on weather information integration strategies.

Part III of the Self-Evaluation Guide provides guidance on components of a typical weather integration plan, including a sample outline and also included in Section 4.5 herein.

3.2 Development of the Self-Evaluation Guide

The construction of the guide began with the identification of a comprehensive list of weather and road weather events that could be considered to have an impact on traffic management activities. This comprehensive list included questions related to the frequency, duration, and intensity of the weather events. The list of weather events was vetted with members of the road weather community to ensure completeness of the list and the appropriateness of the weather event characteristics. The weather events were evaluated as to the possible impacts on traffic management decision-making and to identify the methods needed to provide awareness of the presence or potential of the weather event to the TMC. Table 2 describes the weather events and their definitions identified for the guide.

Using the awareness of weather events of interest to TMCs, a matrix of weather strategies was constructed to identify actions that could be carried out to utilize weather information on the weather events to support TMC decision-making. The development of this matrix included the construction of conceptual weather scenarios for various geographical areas and the anticipated actions that would result within a TMC serving the area. These desktop case studies provided valuable insight into the actions that could benefit from integration under various weather strategies.

Table 2. Descriptions of Weather Events

Weather Event	Description
Drizzle and Light Rain	Drizzle is precipitation consisting of numerous minute droplets of water less than 0.5 mm (500 micrometers) in diameter. Drizzle may also appear to float on air currents but, unlike either fog or mist, it does fall to the ground. Light rain is generally precipitation of 0.10 inches an hour or less. Even light rain can cause flooding if the duration of the rainfall event is long enough or if the runoff conditions are extreme.
Moderate to Heavy Rain	Moderate Rain is defined as falling at up to 0.30 inches an hour. Moderate rain can possibly cause flooding if it lasts long enough or if conditions are such that rain must run off (rather than soak into the ground) and that runoff is concentrated in a small enough area. Heavy Rain is precipitation falling faster than 0.30 inches an hour. Heavy rain can certainly cause flooding. The likelihood of flooding depends on ground conditions and opportunities for the rain water to soak into the ground or to disperse over a large area for runoff.
Severe Thunderstorms	A thunderstorm that produces a tornado, winds of at least 58 mph (50 knots), and/or hail at least 3⁄4" in diameter. Structural wind damage may imply the occurrence of a severe thunderstorm. A thunderstorm wind equal to or greater than 40 mph (35 knots) and/or hail of at least 1⁄2" is defined as approaching severe.
Thunderstorm with Rain	A thunderstorm is a local storm produced by a cumulonimbus cloud and accompanied by lightning and thunder. While usually accompanied by rain, this is not required for a thunderstorm to exist. When rain is present with a thunderstorm, the presence of rain is added to the report of the thunderstorm.
Flooding	High water flow or an overflow of rivers or streams from their natural or artificial banks, inundating adjacent low-lying areas.
Flurries and Light Snow	Snow flurries and light snow are intermittent snowfall of short duration with no measurable accumulation.
Moderate to Heavy Snow	Moderate snow generally means a steady snowfall with accumulations less than 4” in depth in 12 hours or 6” in depth in 24 hours. Heavy snow generally means snowfall accumulating to 4" or more in depth in 12 hours or less or snowfall accumulating to 6" or more in depth in 24 hours or less
Blizzard	Severe winter weather lasting three or more hours in which there is freezing temperatures, sustained strong winds or frequent wind gust over 35 miles per hour, and heavy amounts of snow falling or blowing frequently reducing visibility to ¼ mile or less.
Sleet, and Freezing Rain	Sleet, also known as ice pellets, is rain that freeze into small bits or pellets of ice that rebound after striking the ground or any other hard surface. Freezing rain is rain that freezes on impact to form a coating of ice upon the ground and on the objects it strikes. For both sleet and freezing rain the accumulation of even low amounts quickly reduces vehicle wheel traction and makes driving hazardous.
High Winds	Sustained winds of 40 mph or greater for a duration of one hour or longer or frequent gusts to 58 mph or greater.
Blowing Snow	Wind driven-snow that reduces visibility and causes significant drifting. Blowing snow may be snow that is falling and/or loose snow on the ground that is picked up by the wind to heights of six feet or greater.

Table 2. Descriptions of Weather Events (continued)

Weather Event	Description
Bridge Frost, Road Frost	Bridge and road frost is the accumulation of ice crystals on the bridge or roadway surface. Both bridge and road frost occur when: • The surface temperature is at or below the dew point temperature *and* the surface temperature is below freezing.
Blowing Sand or Dust	Sand or dust that is raised by the wind to heights of six feet or greater.
Smoke, Mist, Fog, Smog or Haze	Smoke in various concentrations can cause significant problems for people with respiratory ailments. It becomes a more universal hazard when visibilities are reduced to 1⁄4 mile or less. Mist is precipitation so light that it can sometimes hang in the air. Mist, in general, poses no threat of flood or damage. Although, by reducing visibility and/or promoting the growth of mold it may present some problems. Fog is water droplets suspended in the air at the Earth's surface. Fog is often hazardous when the visibility is reduced to 1⁄4 mile or less. Originally smog meant a mixture of smoke and fog. Now, it means air that has restricted visibility due to pollution or pollution formed in the presence of sunlight--photochemical smog. An aggregation in the atmosphere of very fine, widely dispersed, solid or liquid particles, or both, giving the air an opalescent appearance that subdues colors.
Tornadoes	A violently rotating column of air, usually pendant to a cumulonimbus, with circulation reaching the ground. It nearly always starts as a funnel cloud and may be accompanied by a loud roaring noise. On a local scale, it is the most destructive of all atmospheric phenomena.
Tropical Storms and Hurricanes	A tropical storm is a distinct rotary circulation with constant wind speed in the 39-73 miles per hour (34-63 knots) range. A hurricane is a tropical cyclone in the Atlantic, Caribbean Sea, Gulf of Mexico, or eastern Pacific, which the maximum 1-minute sustained surface wind is 64 knots (74 mph) or greater.
Temperature Extremes	Extreme heat making it feel very hot, typically above 110 °F for 3 hours or more during the day and at or above 80 °F at night. Extreme cold temperatures generally are defined differently by geographical areas, but are generally colder than -30°F.

Weather integration can take on many forms and involve several strategies to effectively use information about weather to make operational decisions. For the Self-Evaluation Guide, the weather information framework of a TMC is described using eleven items of integration as follows:

1. Use of Internal Weather Information Resources
2. Use of External Weather Information Sources
3. Availability of Weather Information
4. Frequency of Weather Forecasts
5. Frequency of Weather/Road Weather Observations

6. Weather Information Coordination
7. Extent of Coverage
8. Interaction with Meteorologists
9. Alert Notification
10. Decision Support
11. Weather/Road Weather Data Acquisition

These items represent both the state-of-the-practice as well as the best practices observed at various TMCs around the country as determined in the prior weather integration study. For each item of integration, five different levels of integration were identified.

Table 3 shows the different levels. These levels (methods) range in degree of sophistication from fairly simple to quite complex. The levels are associated with requirements pertaining to technology, institutional capabilities, procedural and operational policies and physical infrastructure.

During the development of the weather integration strategies, it became clear that the language of weather integration and the items of integration by themselves might not fit well with the perspective of the TMCs who may have different views of the purpose of weather integration. To capture their integration needs, a list of operational needs was developed. This list of operational needs (what a TMC hoped to do in terms of operations during a weather event) were then mapped to the weather integration strategies and levels.

Table 3. Item(s) of Integration Matrix

Item of Integration (Broad Requirement/Concept)	Levels of Integration					
	None	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**
Use of Internal Weather Information Resources	None	Camera imagery	Radar, satellite, ASOS and AWOS data, and general zone-type forecast information	Level 2 data plus data from RWIS and related networks	Level 3 data plus data from Automatic Vehicle Locations/Mobile Data Computers 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	None	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	None	Cable channel or subscription weather information vendor providing general weather information	Internet provided weather radar or satellite image on video wall	Field observers or 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	None	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
Frequency of Weather/Road Weather Observations	None	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

Table 3. Item(s) of Integration Matrix (continued)

Item of Integration (Broad Requirement/Concept)	Levels of Integration					
	None	Level 1	Level 2	Level 3	Level 4	Level 5
Weather Information Coordination	None	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 EOC/OEM
Extent of Coverage	None	Sparse Set of Isolated Locations	Network of Scattered Locations	Corridor-level	Multiple-corridor/sub-regional	Regional/Statewide
Interaction with Meteorologists	None	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	None	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
Decision Support	None	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	None	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

Each cell in the example below (Table 4) represents the minimum level under each item of integration that will address the operational need. For example, to address a TMC operational need for "better short-term forecasts of arrival time, duration, and intensity of specific weather events at specific locations [ROW1]", the mapping suggests that integration at Level 3 is required for the item of integration called "Use of Internal Weather Information Resources [COLUMN 1]" and at Level 4 for the item of integration called "Use of External Weather Information Resources."

Table 4. Example from the Items of Integration Matrix

Needs/Integration Mapping (Numbers indicate the level of integration at which this need can be reasonably addressed)	Use of Internal Weather Information Resources	Use of External Weather Information Sources
Better short-term forecasts of arrival time, duration, and intensity of specific weather cells (events) at specific locations	3	4

The results of the weather strategy mapping served as the foundation for the weather integration guidance document. Table 5 shows how TMC operational needs (in rows) are mapped to the items of integration (columns) in the Self-Evaluation Guide.

Table 5. Needs vs. Item(s) of Integration Matrix

Needs/Integration Mapping (Numbers indicate the level of integration at which this need can be reasonably addressed)	Use of Internal Weather Information Resources	Use of External Weather Information Sources	Availability of Weather Information	Frequency of Weather Forecasts	Frequency of Weather/ Road Weather Observations	Weather Information Coordination	Extent of Coverage	Interaction with Meteor-ologists	Alert Notification	Decision Support	Weather/ Road Weather Data Acquisition
Weather Information Gathering and Processing											
Better short-term forecasts of arrival time, duration, and intensity of specific weather cells (events) at specific locations	3	4	4	3	3	2	3	3	4		
Better prediction of impact of weather events including assessment of reductions in capacity	3	4	4	3	2	2	3	2	4	3	2
Better real-time information on road conditions during weather events	3	3	3		2	2	3		4	2	3
Improve the coverage and granularity of weather information in the region	3	3	3	3	2		3	2		2	2
Assistance in interpreting weather information and how best to adjust operations in light of that information						2		3		3	
Institutional Coordination											
Develop and implement clear, written policies and procedures for handling weather events						2		3		2	
Improve coordination within the TMC operations						2	3		2	2	
More coordinated responses and information sharing with adjacent jurisdictions/regions						2	4		2	2	
Improve coordination with local public safety and emergency agencies	3	3	3	3	3	3	4	2	4	3	
More opportunities and mechanisms for communications and exchange with others in the weather community and those with experience dealing with weather events								1			

Table 5. Needs vs. Item(s) of Integration Matrix (continued)

Needs/Integration Mapping (Numbers indicate the level of integration at which this need can be reasonably addressed)	Use of Internal Weather Information Resources	Use of External Weather Information Sources	Availability of Weather Information	Frequency of Weather Forecasts	Frequency of Weather/ Road Weather Observations	Weather Information Coordination	Extent of Coverage	Interaction with Meteor-ologists	Alert Notification	Decision Support	Weather/ Road Weather Data Acquisition
Advisory Operations											
Disseminate weather information to a larger set of stakeholders and users in the region (including transit and other modes)						2	4		2	2	
Improve message content (for DMS, 511, HAR, websites etc)	3	4	4	3	3	2	3	2		2	3
Improve targeting of weather messages (site-specific, user group specific) to more effectively convey road weather information	3	4	4	3	3	2	3	2		2	3
Provide better pre-trip weather information to aid travelers in their decision making	3	4	4	3	3	3	5	2	4	2	2
Provide better en-route weather information to aid travelers in their decision making	3	4	4	3	3	3	5	2	4	2	2
Control Operations											
Improve management of emergency routing and evacuation for large-scale weather events	3	3	3	3	3	2	5	3	4	1	2
Improve traffic diversion and alternate routing capabilities	3	3	3	3	3	2	3	2	3	3	2
Improve safety at intersections during weather events	4	4	4	4	4	4	4	3	4	3	4
Improve traffic signal timing during weather events to facilitate traffic movement	4	4	4	4	4	4	4	3	4	3	4
Treatment Operations											
Assist maintenance in better determining the optimal treatment materials, application rates, and timing of treatments	3	4	4	3	3	3	3	3	3	2	2
Improve the timeliness of weather management response including deployment of field personnel and equipment	3	4	4	3	3	3	4	3	3	3	2
Reduce the time required to restore pre-event level of service operations after a weather event	1	2	3	1	1	2	3		2	2	3
Reduce costs of roadway treatment options	4	4	4	4	4	4	4	3	4	3	4

4 Selecting and Working with Two Test TMCs

4.1 Selection of the Test TMCs

The objective of the TMC selection process was to identify two candidate TMCs willing and motivated to use the draft Self-Evaluation Guide to identify candidate weather integration strategies appropriate to their circumstances and needs. Then, based on the weather integration strategies selected by the TMC, each TMC was asked to develop an integration plan that would detail the steps they would need to take to implement those strategies in their TMC. The project team would work closely with the TMC to support these activities and identify lessons learned from the TMC's experience in both the self-evaluation and planning processes. As a result of assisting the two TMCs to implement the Self-Evaluation Guide to develop integration plans, the project team also hoped to obtain feedback that could be used to refine and improve the Self-Evaluation Guide.

The project team, working closely with FHWA, identified ten potential TMC candidates. Most of these TMCs came from the original study and information was already known about their operations, level of weather integration, and types of weather events. From this list, two TMCs were selected to work with the project team and FHWA.

The two primary expected outcomes from working with the each of the TMCs included:

- Input to assist in the refinement of the electronic version of the Self-Evaluation Guide.
- A weather integration plan that would define how the results of the self-evaluation could be used to make improvements in the integration and use of weather information at the TMC.

Selection Criteria
Criteria were established to select the two candidate TMCs most likely to successfully complete the self-evaluation and planning process. The criteria included:

1. Interest in improving weather integration in their TMC.
2. Willingness and motivation to participate in this study with the project team and the FHWA.
3. Willingness and motivation to develop a weather integration plan.
4. Diversity and representativeness by type of operations (regional vs. statewide; urban vs. rural; freeway vs. arterial; etc.).
5. Range of primary weather events and impacts.
6. Current level of weather integration (high, medium or low).

The primary criteria focused on a TMC that had a recognized need to better integrate weather information in their operations and a strong desire to learn more about weather integration strategies and implement those strategies and methods in the near term. A high level of motivation to participate was considered critical to the success of this project. While it was recognized that two TMCs could not possibly represent all TMCs across the country, the

selection process sought to identify TMCs that reflected diversity among major weather patterns and transportation conditions.

Table 6 displays the top ten TMCs considered along with information and responses for each of the selection criteria. All of these TMCs were interviewed by phone and asked a consistent set of questions developed by the project team to help collect the appropriate information. Of the ten TMCs interviewed, four expressed no interest, three indicated a low to moderate interest, and three were excited about the opportunity (indicated with italic text and yellow highlighting in Table 6), mentioning that such an activity fit nicely with their current expansion plans. Those that indicated a general lack of interest in enhancing weather information in the TMC did so either because they felt they had what they needed, or weather information was not among their primary operational concerns at this time. The three TMCs that expressed a strong interest in participating are described in more detail below.

Selection of Two TMCs

Two of the three TMCs were recommended for participation in the study and the third was designated as an alternate. The two TMCs were selected because it was felt they expressed the strongest motivation and need for future weather integration. Both of the two TMCs identified below executed a Memorandum of Understanding between the project team and TMC management that outlined the expectations and responsibilities of each project participant.

- **Sacramento, California:** This Caltrans District 3 Regional Transportation Management Center (RTMC) is responsible for a large region that includes two major general and commercial travel corridors (I-5 and I-80). Although they only have responsibility for the freeway systems, their purview spans urban and rural areas and includes vast differences in weather environments. The weather events that significantly impact their operations include both heavy rain (with corresponding flooding) and major snow events on I-80's Donner Pass that can frequently close this primary Interstate route. They recognize that they lack adequate weather information in the RTMC, and they desire to improve their capability to integrate weather information into their operations. They welcomed the opportunity to work with the project team to help them achieve their goals, and they agreed to prepare the required weather integration plan following completion of the electronic self-evaluation process.

- **Milwaukee, Wisconsin**: This Statewide Transportation Operations Center (STOC) has recently been expanded to include responsibility statewide throughout Wisconsin. As such, they are responsible for a variety of urban and rural roadways including freeways and major arterial corridors that include signal system responsibility. Snow storms are the primary weather events that impact traffic operations. They have identified a need to improve their weather information and integration within the center and have begun an internal effort to define what that means. They wanted to include the outcomes of the self-evaluation in their a pre-existing winter emergency response plan, rather than preparing a separate weather integration plan.

Alternate

The following TMC was selected as an alternate; however, because the first two TMCs were able to participate in this study, there were no further discussions with the alternate. The alternate site would only be involved in the study if one of the other TMC sites decided not to continue their intended participation.

Atlanta, Georgia: This large regional TMC is currently in the planning stages of making significant updates to their Advanced Traffic Management System (ATMS) software and traffic management operations. This TMC's operation is primarily affected by heavy rain and flooding. They also experience snow/ice events that can have an impact on traffic conditions. They acknowledged the need to improve their weather information and are interested in knowing more about the best ways to achieve that. They expressed an interest in working with the project team to help them achieve their goals.

Table 6. TMCs Interviewed for Participation in the Project

TMC Location	Regional Location	Interest in improving Wx Integration	Willingness to Participate in study	Willingness to Develop Integration Plan	Type of Operations	Primary Wx Events/Impacts	Current Wx Integration
Atlanta, Georgia	*Southeast*	*Yes. Want to do better job of Wx integration.*	*Yes. Planning to revamp ATMS system*	*Yes*	*Regional, urban, freeway*	*Heavy rain, flooding, some snow/ice*	*L to M*
Cincinnati, OH	North Central	Strong maybe. Checking with ITS ODOT coord.	Uncertain	Uncertain	Regional, urban, freeway	Snow, ice, rain, flooding	L to M
Columbus, OH	North Central	Maybe. Didn't show strong interest.	Uncertain	Uncertain	Regional, urban, freeway	Snow, ice, rain, flooding	L to M
Hampton Roads, VA	Northeast	No. They get all the weather info they need.			Regional, urban, freeway	Snow, blizzard, ice, rain, flooding	M to H
Kansas City, MO	North Central	No. Wx not a priority. Does not see value.			Regional, urban, freeway	Snow, blizzard, ice, wind, rain, flooding	L to M
Milwaukee, WI	*North Central*	*Yes. They are beginning an effort to define Wx integration now.*	*Yes. They recently became the statewide center.*	*Yes*	*Statewide, urban and rural, freeway and arterial corridors*	*Snow, blizzard, high winds, rain, flooding*	*L*
Phoenix, AZ	Southwest	No. The RWIS in the north is working well.			Statewide, urban and rural, Freeway	Heavy rain, flooding, some snow/ice	L
Rochester, NY	Northeast	No. Get what they need and Wx not a priority.			Regional, urban/rural, freeway and arterials	Snow, blizzard, ice, wind, rain, flooding	M to H
Sacramento, CA	*West*	*Yes. Want to improve Wx info integration.*	*Yes. Need to improve goods movement*	*Yes*	*Regional, urban and rural, freeway*	*Snow, ice, rain, flooding*	*L to M*
VDOT Northern VA Smart Traffic Center	Northeast	Maybe. They are redoing their ATMS system. May be wrong timing.	Uncertain	Uncertain	Regional, urban/suburban, freeway and arterials	Snow, blizzard, ice, rain, flooding	L

4.2 Site Visits with the Test TMCs

The project team's scope of work included sites visits to both of the two selected TMCs to assist them in working with the Self-Evaluation Guide through the self-evaluation process and in developing their weather integration plans. Two site visits were planned for each TMC and focused on the following topics:

- Site visit #1: Introduce the TMCs to the draft Self-Evaluation Guide and assist them in using the Self-Evaluation Guide. Also, obtain feedback regarding improvements to the Self-Evaluation Guide.
- Site visit #2: Review the TMC's self-evaluation outcomes and discuss the preparation of the weather integration plan. Also, obtain feedback regarding improvements to the Self-Evaluation Guide and the self-evaluation and plan development processes.

Prior to the first visit and throughout the process several phone conversations took place between the TMC group and the project team to ensure the TMC had the support they needed to fully complete the self-evaluation and prepare the weather integration plan. Also, these phone conversations served as a mechanism for the project team to receive important feedback about the use of the Self-Evaluation Guide and future needed improvements.

First Site Visits

A first site visit was made to both Sacramento, California and Milwaukee, Wisconsin. Prior to the first site visit the TMCs were provided the initial electronic version of the Self-Evaluation Guide and a hardcopy of the Self-Evaluation Guide documentation to assist with their understanding of the Self-Evaluation Guide and expectations for their engagement in the self-evaluation and planning processes. A phone conversation took place with the leadership at both TMCs after the Self-Evaluation Guide and the documentation were provided (but before the site visits) to ensure they understood the material and to encourage them to start using the Self-Evaluation Guide before the project team arrived.

The topics during the first site visits included an introduction to the project and objectives of the meeting, actively working through the Self-Evaluation Guide and the progress the TMC had made so far, identifying any problems encountered and potential improvements to the Self-Evaluation Guide, translating the Self-Evaluation Guide results into an integration plan, and wrap-up/next steps. Summaries of the meeting notes from these visits are provided below.

Second Site Visits

Following the first site visits, it was clear that both TMCs needed to work further with the electronic version of the Self-Evaluation Guide in order to determine the most relevant weather strategies that the TMC could consider pursuing. The project team continued to make revisions to the Self-Evaluation Guide and provided both TMCs with a third version of the Self-Evaluation Guide from which to work during their final iterations.

Additional phone conversations were conducted between the project team and each of the TMCs as they continued to work with the Self-Evaluation Guide in order to assist them through the process and encourage them to begin developing their weather integration plans.

Information regarding these discussions and second site visits are provided below.

Sacramento, CA

The second site visit to Sacramento focused on the final outcomes of the Self-Evaluation Guide and a review of an early draft that they prepared of their weather integration plan. Additionally, they noted the following benefits of participating in this process:

- A structured, logical process. Along with the dialogue and consensus-building between the interested parties, the self-evaluation process facilitated conversations the RTMC might not otherwise have had. The documented results made practical sense to the RTMC and helped them formulate, define and prioritize their needs.
- Awareness of current and needed integration. It helped them quantify where they were with respect to integrating weather information in their operational decision-making and assisted with prioritizing implementations.
- Justifiable weather integration strategies. The recommended strategies that emerged from the self-evaluation process were not a surprise, but the Self-Evaluation Guide was envisioned to help the RTMC justify the allocation and implementation of their budgets in an environment of limited funding.
- Excellent learning tool. The Self-Evaluation Guide helped facilitate the process of understanding and building consensus on needed weather integration strategies and understanding what weather integration strategies are possible.
- Consistency with operational planning. This process supports and fits in with other related planning, and in one form or another many of the strategies that emerged from the self-evaluation are already in those documents.

Their planning team provided some additional suggested improvements to the Self-Evaluation Guide to help clarify the outputs, easily export the Self-Evaluation Guide outputs (reports) into Word documents, and clean up some language and inconsistencies. These inputs contributed to further Self-Evaluation Guide refinements.

Milwaukee, WI

The project team did not experience the same level of success with the Milwaukee STOC as with the Sacramento RTMC. Between the first and second site visits, Wisconsin DOT changed the focus of their Winter Event Emergency Response Plan (WEERP) to became the Winter Event Communications/Coordination Plan (WECCP). This plan did not include the weather integration strategies that were outcomes of the self-evaluation process. The Milwaukee STOC management decided they no longer had a need for additional weather integration plan components. Consequently, a second visit to Milwaukee was not conducted, and Wisconsin DOT decided to discontinue their involvement in the project.

Wisconsin DOT made this decision well into the process and after the STOC had been working extensively in conducting the self-evaluation. These efforts by the STOC yielded important and useful feedback to the project team regarding possible improvements to the draft electronic version. Their suggestions were incorporated into the final Self-Evaluation Guide and shared with the Sacramento RTMC. When Wisconsin DOT decided not to produce a stand-alone weather integration plan, the project team had the option to contact the alternate TMC in Atlanta,

GA. It was decided not to initiate the full self-evaluation and planning process with Atlanta because the project was nearing completion and the Milwaukee STOC had significantly contributed to improving the final product. It was thought that contacting the Atlanta TMC this far into the project would have significantly delayed the project, and budget was not available at that point to initiate the process from the beginning with another TMC.

4.3 Observations from TMC Experiences

The following observations are offered regarding working with the TMCs to determine possible weather information integration enhancements through using the Self-Evaluation Guide:

- The Self-Evaluation Guide deals with complex subject matter and therefore requires a focused and committed effort to realize useful results specific to a particular TMC.
- Working through the Self-Evaluation Guide and providing thoughtful and informed responses required TMCs to have knowledgeable and experienced maintenance and operations staff to execute the self-evaluation. It would not be appropriate to ask entry-level TMC personnel to work through the Self-Evaluation Guide.
- The process of working through the self-evaluation as a group was essential and beneficial for the following reasons:
    - Different perspectives expressed and shared.
    - Synergy helpful.
    - Improved results.
- The dialogue between maintenance field supervisors and TMC operations management was of great value for the following reasons:
    - Recognizing their different roles and understanding their different perspectives.
    - Initially taking a group approach to the self-evaluation judged better than individually completing the self-evaluation and then coming together as a group to try to integrate the results.
- Going through Sections 1 and 2 was critical to executing the rest of the self-evaluation and affected outcomes. Having a good understanding of the type of weather events and quantifying their impacts on TMC operations are critical because they establishe the context for considering alternative strategies for selecting integration enhancements, even though these initial sections do not directly impact the selection of strategies for consideration.
- In making judgments about need priorities, the TMCs started with their high priority needs and then considered their funding resources to add a sense of realism.
- Outputs of the Self-Evaluation Guide were confirmed by independent analysis by TMC management and other participants – they felt comfortable with self-evaluation results and recommendations.
- The Sacramento RTMC thought this process may lead to a shift of some current longer-term priorities to nearer-term. Their weather integration plan was envisioned to become part of their ITS deployment plans, and was expected to feed into their corridor management plans. They want this to become “part of our logic,” rather than an isolated weather plan.

4.4 Refinement of the Self-Evaluation Guide Based on TMC Experiences

Overall, the process of working with the TMCs to test and refine the Self-Evaluation Guide was essential. The resulting final Self-Evaluation Guide is much improved over the original, due in large part to the invaluable input from both the Sacramento and Milwaukee TMCs. Early versions of the Self-Evaluation Guide still needed several improvements, and both TMCs contributed in a significant way toward identifying the needed changes and enhancements to the Self-Evaluation Guide. In addition to identifying and correcting editorial issues, the reviews and use of the guide by the TMCs provided ideas for refinement in two major areas – conceptual, and database design/application. The conceptual issues have been addressed but the database/application issues still persist and are prime candidates for future guide refinement.

Conceptual Issues

Issue – Understanding the definition of weather event. For example, what does flooding mean – only a major event or anytime water is on roadway? How it occurs affects what the TMC does in response. Consider the difference between a dip in the road that may "pond" versus a levy that breaks and floods a wide area.

Resolution – Included more precise definitions of weather event terms and clearer definitions of weather impacts on TMC operations in the refined Self-Evaluation Guide. The sites also noted that it is not as important that definitions are perfect, but rather that all the participants reach consensus on the definitions of the terms together and work with the same definitions throughout the process.

Issue – Non-homogeneity of TMC region. Sacramento RTMC selected many high-level integration strategies in Section 3 of the Self-Evaluation Guide (the current weather management framework) because they were conducting those activities somewhere (geographically) in their program. However, they also identified several "needs" that would suggest they do not have the integration capabilities. Both were true. What they were really saying is they were integrated in some locations or aspects of the TMC operations, but not enough and they needed significant improvement in that area of weather integration. They asked, "How do we work with the fact that we are doing well in this location but not in that location?" This resulted in the Self-Evaluation Guide not recommending many new strategies because it showed that they were already doing it.

Resolution – The issue was resolved by the TMC by conducting the self-evaluation separately for different segments within their districts. The Sacramento RTMC initially began with a focus on their entire District, but they discovered a lot of variability in weather, its effects on traffic, and the differences in existing levels of integration. They found more value in focusing on segments within their District that have high priority weather needs that they have to actively manage. This approach led to a more sensible prioritization of their integration needs.

Database/Application Issues

Issue – Lack of Microsoft Access 2003 at TMCs. One of the TMCs did not have the right version of Microsoft Access, which is required for the Self-Evaluation Guide.

Resolution – Unable to resolve this issue at this time. It is important to remember that this is a prototype tool to assist state and local agencies in the self-evaluation process and the purpose of this tool was to provide FHWA with a proof-of-concept tool showing that the self-evaluation could be automated. For ease and convenience in programming, the project team elected to develop the prototype tool in Access 2003; however, to promote widespread use of the tool, the tool, or at least the front-end user interface, needs to be converted into a web-based format.

Issue – Converting Access reports to an editable format. The TMCs noted they would like to be able to convert the reports from the self-evaluation into an editable format.

Resolution – Limitations in Microsoft Access prevent them from easily doing that. While this issue is a prime candidate for refinement in the next version of the guide, currently, a roundabout way has been used to convert the reports into a partially-editable format. The reports were converted to a .pdf (Adobe Acrobat) file and a commercially available file conversion software (Able2Doc) was used to convert the .pdf file to Microsoft Word format.

4.5 Plan Components and Guidance for TMCs

The efforts of the project team working with the TMCs had two major components:

- Execute the Self-Evaluation Guide to determine the most appropriate weather integration strategies.
- Develop a weather integration plan that addresses how the strategies would be implemented at the TMC.

The objective of both these components was for the TMCs to learn enough about using the Self-Evaluation Guide to provide meaningful feedback to improve the Self-Evaluation Guide before it would be released to a wider group of TMCs. This was achieved. Excellent feedback was received by the project team and incorporated into the final Self-Evaluation Guide.

The purpose of the weather integration plan was to provide a roadmap and a schedule for the TMC to follow in implementing the weather integration strategies that were identified from the self-evaluation. The integration plan will reflect the unique preferences and requirements of the TMC, including the current level of weather integration that is already in place.

The following draft outline was provided to the two TMCs that offers planning elements that are broadly applicable for consideration by any TMC. TMCs may also consider seeking assistance in conducting the self-evaluation, developing their integration plans and implementing the weather integration strategies.

I. Introduction – A general overview of the weather integration plan document. The following sections may be included:

A. Purpose and Benefit – An overview of the weather integration activity, the purpose it is expected to serve, the anticipated benefits to be derived from enhanced integration, and the process used to develop the integration plan.

B. TMC Overview – An overview of the TMC and its responsibilities. Include a description of the region, current and projected weather integration, and the factors that make weather integration important to its operations.

C. Weather Integration Self-Evaluation Process – Briefly describe the process that was used to identify weather integration priority needs and integration strategies for inclusion in the weather integration plan for the region. Describe the needs identified in the self-evaluation, why they are important to the TMC, and how they build on current weather integration goals.

D. Relationship to Other Plan Documents – A brief overview of how this integration plan relates to other planning and deployment documents in the region, including the Regional ITS Architecture and the Regional ITS Deployment Plan.

II. TMC Weather Integration Plan – This section will be the main section of the integration plan. The development of the integration plan will follow a general planning process.

A. Inventory Existing Weather and Transportation Management Systems – An overview of the existing road weather management information and decision-support systems in the region.

B. Concepts of Operations – Describe concepts of operations for management and decisions-support systems and strategies that utilize integrated weather information to support TMC functions. This section may also describe how regional goals and objectives are achieved by implementing the concepts of operations.

C. Integration Needs – Identify and discuss the high priority weather information operational needs that have influenced the selection of weather integration solutions.

D. Integration Solutions – Identify and discuss how the weather integration needs will be addressed by each of the strategies/solutions identified through the self-evaluation. Potential items to be discussed in this section include the following:

- What will the TMC do differently?
- Will operational functions be modified, eliminated, or added?
- Will there be changes in stakeholder and agency interaction and data exchange?
- Will traffic management be performed more pro-actively?
- Will there be new or altered data or information exchanges?
- How will the performance of the TMC and the transportation system change as a result of implementing the integration strategies?
- Will there be new agreements needed?

The weather integration plan should also address in this section how the potential integration solutions will affect the five dimensions of integration (Operational, Physical, Technical, Procedural, and Institutional) for the TMC. These dimensions are defined in greater detail at the beginning of Section II-6 of the Self-Evaluation Guide, and examples are provided for each item of integration throughout that section. Assessing the effects of

each potential integration solution within these dimensions will help the TMC understand, and best plan for, the full impact of implementing each solution.

III. Implementation of Integration Plan – Identify the projects and strategies that are required in order to implement the integration plan.

A. Integration Schedule (Phasing and Sequencing)

- **Implementation Timeframe** – Identify when the various TMC weather integration projects will be initiated and completed.
- **Sequencing of Strategy Implementation** – Describe how the strategies associated with each project will be sequenced and coordinated.

B. Cost Estimates – Provide estimates of the anticipated costs that are expected to be incurred by implementing the projects and strategies identified in the integration plan.

- **Deployment** – Estimated costs of the hardware and software components needed.
- **Integration Life-Cycle Costs** – Total life-cycle costs associated with deploying, operating, and maintaining the hardware and software components of the system.

C. Operations and Maintenance Requirements – Highlight the operations and maintenance requirements that will be needed to support the integration efforts. Consider the following:

- **Staffing** – Staffing requirements (number and qualifications) needed to provide long-term support and maintenance of an integrated system.
- **Support** – Financial support that will be needed to provide for the long-term operations and maintenance of the system.
- **Training** – Training requirements needed to provide long-term operational support and maintenance of the integrated system.

D. Anticipated Challenges and Constraints of Integration – Identify challenges and constraints to weather information integration and discuss how the TMC will address them during implementation. Additionally, identify the steps required to ensure success.

Section I – Introduction sets the stage for working with the Self-Evaluation Guide and development of the Weather Integration Plan. It establishes the project purpose, describes the TMC characteristics, explains the process used, and identifies any other planning documents used or affected by the process. Section II – TMC Weather Integration Plan begins by inventorying existing weather information and integration sources and systems. Next, it documents the TMC concept of operations and focus of the weather integration self-evaluation, identifies the weather integration needs, and results in weather integration strategies for consideration. As part of the last portion of this section of the Weather Integration Plan, it explains which strategies were chosen and why they were deemed the most appropriate for implementation. The final section of the Integration Plan, Section III – Implementation Plan describes the schedule, costs, Operations and Maintenance (O&M) requirements and anticipated challenges associated with implementing the weather integration strategies chosen from the candidates listed in the Self-Evaluation Guide.

This weather integration plan outline was provided to the two TMCs as guidance for them to produce their plans. It was meant to be comprehensive, but not too over burdensome. As previously mentioned, Milwaukee STOC elected not to produce their weather integration plan. However, Sacramento RTMC did produce their weather integration plan using this outline, and it

is found in Attachment 1. Lessons from the experiences gained while working with Sacramento are summarized in Chapter 5.

5 Lessons Learned

5.1 Plan Development Experiences at the Sacramento RTMC

The experiences of the project team working with the Sacramento RTMC to help them work through their self-evaluation and develop their weather integration plan (see Attachment 1) suggested a number of lessons:

- **A lead integrator is important, but a team is essential.** Preparing such an important document has to be accomplished by a lead author who essentially writes the entire document. However, the lead author can not do this without a team of people who represent the affected disciplines in the TMC or who work closely with the TMC to ensure that weather integration strategies are supported and the integration plan is implementable.
- **The weather integration plan outline was valuable in guiding plan development.** The outline provided by the project team was extremely helpful in preparing the Sacramento RTMC Weather Integration Plan. It provided a roadmap of needed components, rather than leaving them to figure out how to identify those themselves. They found it comprehensive and every section meaningful in planning for future implementation. Two elements of most value were the identification of operational concepts (the Sacramento RTMC identified two scenarios that they decided to evaluate separately) and the establishment of a relationship between their weather integration plan and their other planning documents. These elements ensured that their future integration work would fit with their other TMC operational enhancement plans.
- **Integration plan development is a larger undertaking than originally thought.** Preparing a weather integration plan is an important effort that requires dedicated time. Since these kinds of efforts are above and beyond the normal business of managing and operating a TMC, that time is hard to come by. Consequently, it took much longer than expected to produce a comprehensive plan and gain consensus from the team.
- **The RTMC discovered that the plan development process afforded a valuable learning experience about weather integration.** The effort to execute the Self-Evaluation Guide and produce a plan to implement some of the resulting weather integration strategies was a huge learning experience. This was worth the effort and will benefit the TMC operations in the future by being better prepared to handle severe weather events. One of the primary learning experiences for the Sacramento RTMC was to acknowledge that they have conducted business in a reactionary mode most of the time. Implementing the suggested weather integration strategies would encourage them to change their practice to be more proactive in dealing with weather events.
- **The process may have been more important than the results.** Thinking through their current weather information usage and integration in the Sacramento RTMC and what future enhancements were necessary (based on the needs identified) was extremely valuable to them. The logical, structured process used in executing the Self-Evaluation Guide was extremely helpful and provided the foundation for making decisions about how to move forward. It provided the mechanism to bring the right people together from various disciplines and organization to talk about weather integration and work through the process to determine the best course of action to implementation improvements. The

team that the RTMC assembled to participate in the self-evaluation and planning process included participants who had rarely ever met together as part of their normal jobs.

- **The weather integration planning process presented a unique opportunity for the Sacramento RTMC to review their operational procedures.** The evaluation of the guide and implementation strategies required the RTMC to review many of the internal processes related to all aspects of decision making including but not limited to weather integration. As a result many related processes were reviewed and secondary improvements have begun or resulted from the self-evaluation process. Projects that had earlier been designed to support the decision process in the Sacramento RTMC and were subsequently reduced in priority have been re-energized by this planning process. As a result of this activity, some of the RTMC's original strategies were discovered to be more obtainable than initially anticipated.
- **Integration in the Sacramento RTMC environment is only part of the solution**. It has become clear after reviewing the weather integration strategies that the greatest benefit to the motoring public would result from proactive efforts by both the RTMC and the field maintenance crews. The information collected in the self-evaluation process is used in the field by maintenance crews charged with mitigating the effects of weather events on the roadway. The participation in the self-evaluation and planning processes by appropriate representation from both the field crews and management was critical in identifying and developing strategies that could be successfully implemented.

Many of the observations and lessons accumulated in the course of this project have led to the formulation of recommendations to support weather integration as presented in Chapter 6.

5.2 Conditions for Successful Weather Integration in TMCs

A necessary condition for successful weather integration in TMCs will be the development of 'champions' within each TMC who possess the enthusiasm and determination to better utilize weather information within a TMC's operational practices and who have a clear vision of the benefits and the methodologies for implementation of such strategies. Creating champions within a TMC will be enhanced where raising awareness can be achieved with TMC personnel of the value of weather information and its availability. A potential method to achieve this awareness is through collaborative activities between TMCs such as through the Transportation Pooled Fund activities where weather integration is of primary interest to the participants. For periodic awareness raising, it will be helpful to conduct topical workshops that bring members of the traffic management community together with others in the road weather community to exchange possible solutions to weather-related traffic issues. Past activities supported by the FHWA RWMP to foster greater awareness of road weather capabilities and benefits have been successful in the winter maintenance community. This model would likely achieve similar results in the traffic management community.

Commensurate with the presence of a champion is the fiscal support within the appropriate funding agency to provide the resources and personnel to permit the integration process to proceed from a self-evaluation and plan development stage through to implementation. In situations where weather integration is of interest to a TMC, but a barrier exists in funding, the

availability of Federal incentives might supply sufficient impetus to encourage a TMC to begin the integration planning and implementation process.

The adoption and diffusion of technology within a public organization often depends upon the advocacy of such activities through improving the bottom-line of the organization. In other words, the demonstration of a positive benefit-to-cost is often required before agency administrators will commit to the financial support for change. As such, it is expected that before a widespread acceptance of weather integration within a TMC occurs, there will be a need for benefit-cost studies that demonstrate the fiscal efficacy of these activities.

Finally, it will be necessary for the road weather community, public and private, to respond to the expressed needs of the traffic management community with appropriate data, information, and services to satisfy the defined needs of each TMC moving towards the level of integration deemed most appropriate.

5.3 Challenges and Benefits of Weather Integration in TMCs

One challenge that faces FHWA is getting agencies that have some level of weather integration already occurring in their TMCs to take the next step for a higher level of integration. Many TMCs claim to have weather "integrated" in their TMC because they can receive weather information in their TMC. While this is a start, the need continues for a tighter coupling between access to weather information and the use of weather information as part of an operational decision-making process. Because in many cases where weather does not impact the majority of decisions that are made by operators at the TMC, many agencies feel that just having weather information available in their TMC is enough and, therefore, do not perceive a need for tighter integration. Agencies need to be shown the benefits of a more comprehensive integration of weather information in TMC operations. Strategies and tools need to be developed that can assist TMC operators in making operational decisions that account for or adjust for weather conditions. Using weather information to make both strategic and tactical operational decisions needs to be mainstreamed.

6 Recommendations for Implementation

6.1 Introduction

This project has resulted in the weather integration self-evaluation and planning guide that helps TMCs better understand their weather information/integration needs and identifies future weather integration enhancements. An electronic version of the Self-Evaluation Guide (in Microsoft Access), also a product of this project, helped to organize the process by which the weather integration strategies most applicable to each TMC were determined.

The project team has identified a set of recommendations that encompass the next steps in the continuing process to enhance the level of weather integration in the nation's TMCs. These recommendations are presented in four categories as shown in Figure 4. Generally, the categories and recommendations within each category follow a chronological order. However, this is not always the case. For instance, the project team believes that the Education/Training and Self-Evaluation Guide Implementation recommendations can begin at the same time and be conducted in parallel. The four recommendations within the Guide Implementation category are designed to be conducted in series as they are described. Guide Refinement recommendations also demonstrate a sequential ordering, such that the first recommendation should be considered before the others. The Future Possibilities recommendation is for consideration after many of the other recommendations are completed, several years from now. The project team offers each of these recommendations for consideration for implementation by the FHWA RWMP.

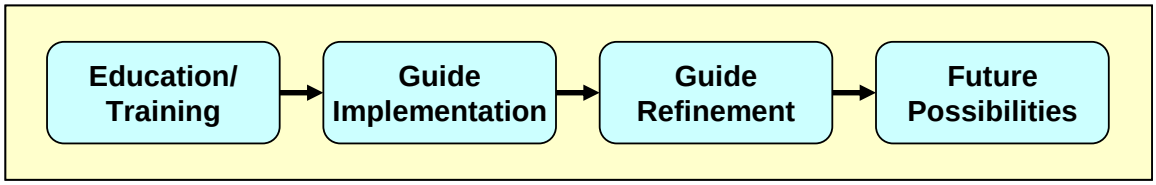


Figure 4. Recommendation Categories

These categories, and the specific recommendations within each, are described in more detail in the sections below. The leadership to help move these recommendations forward and make weather integration a success will of course depend on the FHWA RWMP and on champions for integration within the regional FHWA offices, state DOTs, and other jurisdictions responsible for TMC operations and management. Carrying out effective weather integration requires highly motivated DOT operations managers with support from team members who bring expertise and an understanding of the long-term value of integration to their operations.

6.2 Education and Training

A review of past examples of the adoption of weather integration in transportation decision making indicates that the level of awareness and understanding of weather information, weather impacts on transportation activities, and effective methods to utilize tailored weather information have been critical to the success of the integration efforts. As the weather and road weather information content for TMCs is generated outside of the traffic management community, the ability to understand the roles and responsibilities associated with the generation and utilization

of weather information is paramount to any integration activity. Through an active education program it is possible to heighten awareness and draw together varying perspectives on the efficient utilization of weather information. It is the goal of the RWMP to promote the best utilization of road weather management strategies in decision making. The following three recommendations are being made by the project team to achieve this goal through enhanced education and training.

Recommendation 1: Provide awareness-building of the road weather community regarding the need for targeted/tailored weather information integration in TMC operations.

Issue and Challenge: The lack of use by TMCs of available weather resources, especially those resources specific to road weather, suggests that the road weather community is not adequately aware of the present needs of weather integration by TMCs. This lack of awareness of TMC weather needs further suggests that the road weather service provider community may not be prepared to provide the road weather services tailored/targeted to support traffic management decision-making. This situation serves as a limiting factor in the options available to TMC administrators and operational staff who are interested in pursuing broader weather integration activities. Through increased awareness by the road weather community on the benefits of integrated weather information in TMC operations, the potential exists to develop more appropriate services and methodologies for weather integration through stimulation of new product development and further road weather research.

Recommended Approach: The awareness building being recommended would expose the road weather community to the operational requirements and constraints associated with traffic management decision-making. It would also inform the road weather community of the physical, institutional, technical, procedural, and operational environment of TMCs and provide a means to acquaint the road weather community with the broader traffic management community culture.

It is recommended that the FHWA RWMP develop a program that promotes interaction between TMC administrative and operational personnel and the individuals and organizations within the road weather community. This interaction should promote the awareness of urban and regional traffic operations and traffic management weather-related issues through on-site TMC visitations and joint road weather/traffic management workshops. Emphasis should be on establishing a dialog between the road weather community (public and private) and TMC staff. The RWMP should develop a plan to establish a peer exchange program that would permit members of the road weather community to observe for a reasonable period of time the operational aspects of a TMC.

Expected Outcomes: The expected outcome of implementing this recommendation is an increased awareness by the road weather community of the weather needs of TMC operations and the innovation of new ideas and methods to support TMC weather-related decision-making. This effort would be expected to incentivize the road weather community to address better the weather integration needs and requirements of TMCs. TMC managers

and operators will gain a collateral benefit by the enhanced exposure to the road weather community.

Recommendation 2: Provide awareness-building and training for TMC management regarding the benefits of targeted/tailored weather information integration in TMC operations.

Issue and Challenge: TMC administrators and operational staff often do not fully understand the difference between generic weather products and those targeted/tailored to the surface transportation decision maker. Additionally, they do not understand how integrated weather information (tailored) can support TMC operational effectiveness. It is recommended that in-depth outreach activities, education materials and training be provided to increase the awareness of targeted/tailored weather information sources, tools, and integration of best practices/techniques to improve the effectiveness in responding to weather-impacted traffic events. Through increased awareness of how integrated weather information can benefit TMC operations, there is the potential to have an effect on all the dimensions of integration (operational, physical, technical, procedural, and institutional).

Recommended Approach: The education being recommended here needs to include all aspects and potential benefits of implementing the weather information integration concepts and methods. This would include integrating various sources of road weather information for efficient management decisions as well as the integration of road weather information with traffic operation information.

It is recommended that the road weather community, through assistance from the FHWA RWMP, develop a comprehensive plan to train TMC managers and operators regarding the benefits of integration. This education program should include an effort to increase awareness through workshops/seminars, provide computer-based training materials, and develop and provide a mechanism to deliver a comprehensive course on road weather and traffic management integration methods and benefits. The RWMP should develop a training course that specifically trains practitioners (e.g., TMC operators) in the processes, steps and benefits of integrating weather information into TMC operations.

These education and training programs should draw upon the expertise and creativity of University Transportation Centers, road weather academic community, and the National Highway Institute (NHI) in the preparation and delivery of the education program. The first step will be to increase awareness with a focused package advocating for road weather and TMC information integration. This could include a road show and/or DVD to be presented by RWMP staff at TMCs that would illustrate the benefits and best practices throughout the country. For those TMCs interested in continuing their learning, the computer-based training would go into more detail on specific integration methods and potential implementation approaches. TMCs would be encouraged to complete the computer-based training prior to enrolling in the comprehensive course that would be tailored to a region's or state's needs addressing how to integrate road weather information and traffic operation information in that specific situation. At the conclusion of the education program the TMC operators/management and the road weather community would better understand the needs

of each discipline and the available information, approaches and tools to integrate road weather information in TMC decisions.

Expected Outcomes: The expected outcome of implementing this recommendation is an increased awareness by TMC management of the benefits of integrated weather information to support more effective TMC operations. Increased awareness and understanding is expected to encourage specific ideas of how to implement integrated weather information concepts and methods tailored to the needs of the TMC and motivate early adoption.

Recommendation 3: Promote a partnership between the traffic management and road weather community to foster a sustained dialog on the needs and capabilities of the respective communities.

Issue and Challenge: The traffic management community has not had the same opportunity as the (winter) maintenance community to engage at the local, regional, and national level in discussions of road weather-related issues. The resulting disparity in the maturity of weather usage between the traffic and maintenance communities is evident in the level of integration each has established. In the past decade the maintenance community has benefited from a growing level of partnership established with the road weather community through various action groups that include transportation pooled fund studies, national research initiatives within federal laboratories and academia, and joint national meetings sponsored by the American Association of State Highway and Transportation Officials (AASHTO), FHWA, and the Transportation Research Board (TRB). To afford the traffic management community this same level of partnership will require a commitment by both the road weather and traffic management communities, as well as the FHWA RWMP, to identify clear issues needing to be addressed and to establish a forum by which these issues can be presented and discussed.

Recommended Approach: It is recommended that the FHWA RWMP serve as the catalyst to foster local, regional, and national forums and meetings between the traffic management and road weather communities. As the catalyst to this activity, the RWMP would broker the involvement of appropriate state, federal, academic, and private sector organizations to engage in regular dialog on traffic management issues with TMC personnel. Through its relationship with the TRB and the American Meteorological Association (AMS), the FHWA should develop national stakeholder meetings that utilize the attendees at annual TRB and AMS conferences to bring the two communities together.

It is recommended that the FHWA RWMP host a workshop that would provide a forum for the FHWA to articulate the reasons why weather information is not as tightly integrated into TMC operations as it currently is with regard to the winter maintenance community and to focus on identifying possible solutions to this problem.

The partnership being recommended would provide an instrument to sustain a dialog between the traffic management and road weather communities to promote a broader understanding of the needs and capabilities of each. It would provide an environment for continued growth for each community through knowledge and awareness building.

Expected Outcomes: The expected outcome of implementing this recommendation is a continual dialog between the traffic management and road weather communities on issues of importance to each. It is anticipated that establishing regular meetings will assist in elevating the expectations by each community on the weather integration in TMCs.

6.3 Self-Evaluation Guide Implementation

It is the goal of the FHWA's RWMP to expand the use of the Weather Integration Self-Evaluation and Planning Guide by other TMCs interested in enhancing the use of weather information in their operations. Four recommendations are suggested that are expected to help achieve this goal.

Recommendation 4: Develop and implement a marketing plan to expose more TMCs to the Weather Integration Self-Evaluation and Planning Guide.

Issue and Challenge: The TMC selection process conducted during this project yielded very few organizations interested in participating. Most didn't understand how better integrated weather information could assist them in their operations or just didn't feel further integration was relevant in meeting their needs. The first three recommendations will provide the education necessary to help TMCs understand the importance of weather information and proper integration. In addition to general education, it will be important to market the use of the Self-Evaluation Guide as a tool to help TMCs determine the best strategies to address their operational needs.

Recommended Approach: A comprehensive marketing plan should be developed and implemented with the goal of more TMCs becoming interested in using the Self-Evaluation Guide to help them begin the process of enhancing their weather integration capabilities. The plan should include a set of activities to expose more TMCs to the Self-Evaluation Guide. Possible marketing approaches may include:

- Prepare a brief description of the Self-Evaluation Guide and the benefits offered by its use.
- Adapt elements of the education program (recommendations 1-3) describing the use and benefits of the Self-Evaluation Guide for marketing purposes.
- Distribute information about the Self-Evaluation Guide to TMCs through existing communication channels and networks, including to the TMC Pooled Fund Study participants.
- Prepare a PowerPoint briefing about the Self-Evaluation Guide, and offer presentations and demonstrations at selected conferences and workshops that would involve TMC management.
- Post information about the Self-Evaluation Guide on the FHWA's RWMP website with an easy way to download the Self-Evaluation Guide and documentation and request more information.
- Involve the FHWA Division offices and Resource Centers to actively promote the new Self-Evaluation Guide and prepare them to work with interested TMC managers and operators to support the self-evaluation and integration planning processes.

- Train individuals in the FHWA Resource Center Operations Technical Service Team to be experts on the use of the Self-Evaluation Guide.
- Develop and offer a webinar on the Self-Evaluation Guide and the benefits of its use.

This recommended program includes refinement of the list of marketing approaches (above), implementation of the approaches deemed most effective, creation of a list of interested TMCs, and follow-through on requests for additional information on the use of the Self-Evaluation Guide.

Expected Outcomes: Through the implementation of appropriate marketing plan approaches, it is expected that TMCs would express an interest in using the Self-Evaluation Guide to further their knowledge and use of weather information integration strategies.

Recommendation 5: Select three to five TMCs and assist them in executing the Weather Integration Self-Evaluation and Planning Guide process and in developing a proposal to FHWA to fund a demonstration project.

Issue and Challenge: The key to selecting another group of TMCs to use the Self-Evaluation Guide to help them identify weather integration enhancements is that they are motivated to do so. It will be important that TMCs are contacting the FHWA RWMP with an interest in enhancing their capabilities, rather than the RWMP contacting TMCs almost randomly, not knowing whether they would be interested or not. The results of the recommended marketing activity should yield a number of interested, motivated TMCs that can then be contacted to learn more about their appropriateness as a future participant.

Recommended Approach: An important action for gaining additional interest will be for the FHWA RWMP to fund a weather integration demonstration project (see Recommendation #6 below) for one or two of the TMCs willing to use the Self-Evaluation Guide, and then prepare a request for proposals. It is recommended that three to five TMCs be selected to go through the self-evaluation and planning process and develop a proposal, based on their weather integration plan, to implement the resulting strategies as a demonstration project. These TMCs would receive assistance while conducting this project.

The first step for carrying out this demonstration project would be to refine a set of criteria to select the three to five TMCs. The set of criteria would begin with those used to select the two TMCs for this current project. Through contact and discussions with the list of interested TMCs (from Recommendation #4), additional information would be collected to complete a list of candidates. This process would yield three to five TMCs that desire and are well suited to participate in this phase of a demonstration. Using a similar process to the one used during this current project, TMCs would receive from the RWMP an appropriate level of assistance in the use of the Self-Evaluation Guide, development of an integration plan and demonstration project proposal. It will be important to convey the benefits and challenges expressed by the two TMCs that participated in this project so that the future TMCs fully understand the extent of commitment that will be necessary in order to complete the process. In addition to active participation from the RWMP with each of the selected

TMCs, the project team recommends that three site visits per participating TMC location be conducted, as follows:

- Site visit #1: Introduce the process and the Self-Evaluation Guide; input initial data into the electronic Self-Evaluation Guide and discuss results.
- Site visit #2: Review final weather integration strategies resulting from the TMC completing the self-evaluation.
- Site visit #3: Review a draft integration plan and proposal, and provide feedback.

Expected Outcomes: It is intended that this recommended activity would result in at least three to five qualified and motivated TMCs selected to execute the Weather Integration Self-Evaluation and Planning Guide process and submit weather integration demonstration project proposals to implement the resulting weather integration strategies.

Recommendation 6: Fund a weather integration demonstration project at one or two TMCs.

Issue and Challenge: Most TMCs lack an awareness of the potential benefits of enhancing their level of weather integration, they may believe their current level of integration is sufficient to meet their needs, or they find themselves so busy with the day-to-day operations of their TMC that they don't feel they have the time to engage their management and staff in the further exploration of integration strategies. Also, TMCs on their own typically lack the resources needed to take innovative steps toward greater weather integration; with limited budgets, staffing and time, they focus on meeting their current operational requirements as best they can. One way to overcome this inertia and lack of motivation to engage in the process of self-evaluation and integration planning is to establish a demonstration project with one or two TMCs that can show other TMCs a clear, feasible, and successful pathway to the achievement of greater weather integration.

Recommended Approach: The initiative and resources to establish such a demonstration must presumably come from the FHWA RWMP. The first step involves the selection of the participating TMCs through a request for proposals as described under Recommendation #5. These will include TMCs that have already shown their interest and willingness to participate in the self-evaluation and planning processes, and their motivation to continue on as demonstration sites is confirmed by their decision to submit a proposal to the FHWA RWMP for implementation funding.

This recommendation focuses on taking the weather integration plans prepared by the selected TMCs into full implementation. It is expected that implementation will take at least a year, and maybe two years, to adequately demonstrate the benefits that the TMCs are able to derive from engaging in the weather integration strategies that they selected from the set of strategies that emerged from their self-evaluation.

During the course of the implementation of this demonstration, it is expected that the appropriate FHWA office will play an important oversight role in monitoring progress on the demonstration. It will be essential to keep track of both the technical and financial benefits that can be derived from this demonstration and the institutional lessons learned from the

demonstration. The evaluation of each demonstration project is discussed under Recommendation #7.

Expected Outcomes: The proposed demonstration project is expected to yield two important outcomes. First, one or two TMCs will work through a comprehensive process, starting with a self-evaluation of weather integration needs and preferred strategies, through the development of an integration plan, and continuing through a fully implemented demonstration of higher levels of weather integration in their TMC operations. Second, the demonstration will serve to support the FHWA RWMP efforts to market weather integration more broadly and promote the transfer of effective integration strategies to other TMCs by showing that it is implementable, successful and cost-effective. A question will remain, however, as to whether wide-spread implementation beyond these demonstrations will require FHWA to offer financial incentives in order to encourage additional TMCs to follow the lead of these demonstration sites.

Recommendation 7: Formally evaluate the weather integration demonstration project to ensure the impacts are measured and documented.

Issue and Challenge: The success of this proposed demonstration project in being able to communicate benefits beyond the site itself and will depend on carefully monitoring and evaluating the implementation of the weather integration strategies and sharing those benefits and lessons learned with other TMCs. A particular challenge is likely to be the difficulty associated with documenting a variety of tangible and intangible benefits that are expected to be provided by greater weather integration, such as increased long-term safety, operational efficiencies, increased roadway capacity and mobility, and reduced environmental impacts.

Recommended Approach: As suggested under Recommendation #6, the FHWA field offices are in a good position to support the RWMP in monitoring the progress of their TMC(s) in implementing their weather integration plans. As part of the planning for the demonstration project, it will be useful to identify in advance the performance indicators and the kinds of data that should be collected at the TMC site(s) that can be used to assess the outcomes of the demonstration and in efforts to market weather integration to other TMCs. It is suggested that the evaluation include an economic assessment of the benefits versus costs because other TMCs, which are typically short on resources, will want to understand the cost effectiveness of investments in enhancing their level of weather integration.

Expected Outcomes: An evaluation of one or more demonstrations need to provide results that can be clearly communicated within the TMC community. This could take the form of formal evaluation reports that include graphic representations of progress and benefits achieved based on a pre-demonstration performance versus a post-demonstration performance. The hypothesis associated with this evaluation is that greater weather integration provides improvements in each of the measures of performance noted above. Finally, it is expected that a successful demonstration will provide the evidence base that will convince more TMCs to engage in a self-evaluation and proceed with integration planning and implementation. The long-term goal is to have all TMCs that could benefit from greater levels of weather integration decide to follow this path. The implementation and evaluation

of one or more demonstration projects also will provide the recommended education and training efforts with helpful, tangible insights into the processes and benefits of integration.

6.4 Self-Evaluation Guide Refinement

The weather integration Self-Evaluation Guide is not intended to remain a static, unchanging tool. In order for it to be continually relevant to TMCs, it will be essential to update it on an on-going basis. The following three recommendations address the need for continual improvement and refinement of the entire self-evaluation and planning process for weather integration.

Recommendation 8: Develop a customized front-end user interface to the Self-Evaluation Guide.

Issue and Challenge: The purpose for developing a new user interface for the weather integration Self-Evaluation Guide is to provide FHWA with a proof-of-concept tool showing that the self-evaluation can be fully automated. For ease and convenience in programming within the limited timeframe of the current project, the project team decided to develop the prototype Self-Evaluation Guide in Access 2003. This choice, while allowing for the quick development of the Self-Evaluation Guide, has some limitations in its use, primarily due to the limited reporting capabilities of the software. To promote widespread use of the Self-Evaluation Guide, it is recommended that the user-interface or the front-end of the tool (currently Access Forms and Reports) be converted to a custom-developed web-based application (using a standard programming language like JAVA or Visual Studio).

Recommended Approach: Given the complexities and resources involved in any software development effort, a system engineering approach is highly recommended. A concept of use of the application and requirements should be created before deciding on any software platform or design.

Expected Outcomes: Creating a customized front-end to the Self-Evaluation Guide should result in two main improvements to the Self-Evaluation Guide:

1. Improved reporting capabilities – The interface should include customized reports and the ability to save the results of the evaluation in an editable format. Also, it would be advantageous to have the ability to combine all the reports into a single editable report, a big step towards developing an integration plan.
2. Web-based interface – Allowing for a web-formatted self-evaluation tool could be hosted on FHWA's website and would allow TMCs to access not only the tool itself, but relevant information contained on FHWA's website, such as the *Road Weather Resource Identification (RWRI) Tool***.** Overall, a web-based tool should enhance the accessibility to all TMCs that may have an interest in engaging in the self-evaluation and integration plan development process.

Recommendation 9: Periodically review, validate and update weather integration strategies.

Issue and Challenge: It is important to emphasize that the strategies in the Self-Evaluation Guide not be considered static. While they represent current thinking and a comprehensive

perspective on the state of the practice, TMC operations continue to evolve as well as the weather information and forecasting industry. The integration strategies in the Self-Evaluation Guide need to be reviewed validated and updated as necessary in order to maintain currency and relevance.

Recommended Approach: It is recommended that a small task-force or committee, comprised of both TMC operators and weather experts be established to review the current integration strategies and levels of integration, and validate their relevance and applicability on a periodic basis (suggested about every two years). Changes in the set of strategies would then be incorporated into modifications of the Self-Evaluation Guide in order to keep it as current and relevant to the needs of TMCs as possible. It is also expected that additional lessons learned and input will be received from TMCs using the Self-Evaluation Guide and implementing its integration strategies (recommendations 5 and 6). These inputs will be used as a basis for possible future weather integration strategies.

Expected Outcomes: A current list of best practices for weather information integration would be validated by an expert group and made widely available. In addition, the Self-Evaluation Guide itself would be refined and updated to reflect changes in these strategies.

Recommendation 10: Incorporate more information on the relative benefit-costs into the strategies.

Issue and Challenge: To truly evaluate how to improve their level of integration of weather information, TMCs need information about the relative costs and benefits associated with different weather integration strategies, especially as they consider whether or not to move to the next level. TMCs need to be able to answer the following questions:

- What are the incremental benefits to be achieved by going to the next level of weather integration?
- What are the potential costs associated with taking those next steps?

Obviously, benefit and cost information can become outdated relatively quickly; but TMCs need some idea whether increasing the level of integration to provide more accurate, timely, and focused, weather information produces enough operational benefits to outweigh the costs.

Recommended Approach: The approach for this recommendation is closely linked with the previous recommendations #7 and #9. A committee would be established to review and validate the strategies, and they would also be in a position to assess the relative benefit and costs of the integration strategies. If the RWMP decided to implement a demonstration project with one or more TMCs, the evaluation of the expected improvements in operational performance attributable to increased weather integration would include an assessment of cost-effectiveness.

Expected Outcomes: Increased attention to understanding the relative benefit-cost tradeoffs associated with increased weather integration should lead to increased engagement by TMCs in the self-evaluation and integration planning processes and the development of increasingly useful integration strategies for TMCs**.**

6.5 Future Possibilities

The future possibilities of TMC weather integration will be driven by near-term actions TMCs will take toward implementing higher levels of weather integration. It is anticipated that in time the level of weather integration for a growing number of TMCs will push the technological limits that exist today. The RWMP has demonstrated through its past actions that it embraces the ideal of promoting better decision making through appropriate use of advanced technologies. The following recommendation by the project team is considered a natural extension of present day weather-related decision support tools that can be augmented to provide a valuable asset to TMC decision making.

Recommendation 11: Develop a Traffic Management Decision Support System (TMDSS).

Issue and Challenge: The results of this study involving the self-evaluation and planning process at TMCs, clearly indicate that while TMCs have thought in general terms about incorporating weather information into their decision-making process, they have not fully embraced using weather information to assist them in their day-to-day decision-making process for managing traffic. To better assimilate this decision-making process in their routine operations, TMCs would benefit from advanced guidance tools to assist them in identifying appropriate operational strategies for different types of weather events, both major and minor.

Recommended Approach: The development of a Traffic Management Decision Support System (TMDSS) being recommended would provide a sophisticated method of incorporating decision-making processes within TMCs. This decision support system would be similar in concept to the *Maintenance Decision Support System (MDSS)* presently being deployed by winter maintenance agencies. By integrating relevant road weather observations and forecasts, operational rules of traffic management, and real-time and forecasted traffic conditions, the TMDSS would provide TMC operators with recommendations on road weather management advisory and control strategies to deploy in response to current or impending weather and traffic conditions.

It is recommended that the RWMP engage the road weather community, both public and private, to initiate the development of TMDSS. The TMDSS would allow TMC operators not only to evaluate the impacts of weather factors on traffic management strategies, but also to evaluate the use of different advisory and control strategies to mitigate the impacts of weather conditions on traffic flow. The development of TMDSS should include the appropriate research to expand the development of more effective methods to incorporate traffic models utilizing weather-related factors. The TMDSS also should be used as a planning tool to assist TMC decision-makers who are trying to determine how to best integrate weather information into their TMCs through identification of potential strategies and techniques that can be deployed in their area. The present self-evaluation tool should be integrated with the TMDSS to assist TMCs in identifying weather integration strategies that could be incorporated in an integration plan that supports the implementation of traffic management strategies identified in the TMDSS.

Expected Outcomes: The expected outcome of implementing this recommendation is the establishment of an advanced decision support tool that expands the boundaries of present weather-impacted traffic management decision-making to a level of sophistication that is on par with the winter maintenance community. It is expected that the development of this tool will promote further research and development on TMC weather decision-making leading to greater potential benefits in TMC weather integration and TMC operations.

List of References

Cambridge Systematics. (2003). *Weather-Responsive Traffic Management Concept of Operations (Draft)*. Washington, DC: Federal Highway Administration. Available at http://ops.fhwa.dot.gov/Weather/best_practices/WeatherConOps0103.pdf

Cambridge Systematics and PB Farradyne. (2004). *Roadway Operations Self-Assessment: Version 2.0*. Prepared for Federal Highway Administration.

Cluett, C., Gopalakrishna, D., Kitchener, F., Balke, K., and Osborne, L. (2008). *Integration of Weather Information in Transportation Management Center Operations: Self-Evaluation and Planning Guide* (Prepared for the Federal Highway Administration, Road Weather Management Program). Seattle, WA: Battelle.

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://ops.fhwa.dot.gov/weather/resources/publications/tcmintegration/index.htm

Federal Highway Administration. (2004). *Traffic Incident Management (TIM) Self-Assessment Guide*. Available at http://www.iacptechnology.org/IncidentManagement/TrafficIncidentMgmtAssesGuide.pdf

Federal Highway Administration. (2004). *Work Zone Self-Assessment*. Available at: http://ops.fhwa.dot.gov/wz/decision_support/self-assess.htm

Goodwin, L.C. (2003). *Best Practices for Road Weather Management, Version 2.0* (Report No. FHWA-OP-03-081). Washington, DC: Federal Highway Administration. Available at http://ops.fhwa.dot.gov/weather/best_practices/CaseStudiesFINALv2-RPT.pdf

Lockwood, S., O'Laughlin, J., Keever, D., and Weiss, K. (2005). *Surface Transportation Security, Volume 6: Guide for Emergency Transportation Operations* (NCHRP Report 525). Washington, DC: Transportation Research Board. Available at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_525v6.pdf

National Transportation Operations Coalition. (2004). *Traffic Signal Operation Self-Assessment*. Washington, DC: Institute of Transportation Engineers. Available at http://www.ite.org/selfassessment/

Portaankorva, P. (2002). Road Weather and Traffic Data in Traffic Management. *Proceedings of the 11th International Road Weather Conference*. Sapporo, Japan: SIRWEC. Available at http://www.sirwec.org/en/index.php?page=../conferences/sapporo2002

U.S. Department of Transportation. (2007, April). *National ITS Architecture, Version 6.0*. Available at www.iteris.com/itsarch

Yamada, T. and Maruyama, T. (2002). Construction of a road management support system using information forecast. *Proceedings of the 11th International Road Weather Conference*. Sapporo, Japan: SIRWEC. Available at http://www.sirwec.org/en/index.php?page=../conferences/sapporo2002

ATTACHMENT 1

Caltrans District 3
Weather Integration Plan