Integration of Weather Information in Transportation Management Center Operations: Self-Evaluation and Planning Guide

June 30, 2008

Notice

The U.S. Department of Transportation provides high-quality information to serve Government, industry, and the public in a manner that promotes public understanding. Standards and policies are used to ensure and maximize the quality, objectivity, utility, and integrity of its information. USDOT periodically reviews quality issues and adjusts its programs and processes to ensure continuous quality improvement.

Technical Report Documentation

1. Report No. FHWA-JPO-08-057	**2. Government Accession No.**	**3. Recipient's Catalog No.** EDL# 14437	
4. Title and Subtitle Integration of Weather Information in Transportation Management Center Operations*:* Self-Evaluation and Planning Guide		**5. Report Date** June 30, 2008 **6. Performing Organization Code**	
7. Author(s) Chris Cluett and Deepak Gopalakrishna (Battelle), Kevin Balke (Texas Transportation Institute), Fred Kitchener (McFarland Management, LLC), Leon Osborne (Meridian Environmental Technology, Inc.)		**8. Performing Organization Report**	
9. Performing Organization Name and Address Battelle Seattle Research Center 1100 Dexter Avenue North, Suite 400 Seattle, WA 98109-3598		**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.** DTFH61-06-D-00007; Task BA07-012	
12. Sponsoring Agency Name and Address United States Department of Transportation Federal Highway Administration, Office of Operations 1200 New Jersey Ave., SE Washington, DC 20590		**13. Type of Report and Period Covered** Evaluation Report, 7/18/06 –6/30/08 **14. Sponsoring Agency Code** HOIT	
15. Supplementary Notes Mr. Roemer Alfelor (COTM)			
16. Abstract The Federal Highway Administration's Road Weather Management Program is helping to reduce the adverse impacts of weather on the transportation system by assisting agencies in integrating weather information and technologies into their daily Transportation Management Center (TMC) operations. In order to achieve this goal the TMCs have to evaluate their needs for weather integration and develop a plan to implement strategies that meet those needs. This report presents a self-evaluation guide that helps a TMC identify the relevant weather events in their jurisdiction, determine the type and magnitude of impacts those events have on their transportation system and on TMC operations and traffic management responsibilities, identify current strategies for managing the impacts of weather, prioritize their identified needs for weather information application and integration, and identify integration strategies and solutions that are best suited to meeting the TMC's high priority needs. The results of the self-evaluation serve as input to support the preparation of a weather information integration plan for TMCs. This report is a companion document to the electronic database version of the guide.			
17. Key Words Road Weather Management, Integration, Transportation Management Center (TMC), Self-Evaluation Guide, Weather Integration Planning	**18. Distribution Statement** No restrictions. This document is available to the public.		
19. Security Classif. (of this report) Unclassified	**20. Security Classif. (of this page)** Unclassified	**21. No. of Pages** 90	**22. Price** N/A

Form DOT F 1700.7 Reproduction of completed page authorized.

Table of Contents

List of Tables

List of Figures

INTRODUCTION

The Federal Highway Administration's Road Weather Management Program is helping to reduce the adverse impacts of weather on the transportation system by assisting agencies in integrating weather information and technologies in their daily Transportation Management Center (TMC) operations. In order to achieve this goal the TMCs have to evaluate their needs for weather integration and develop a plan to implement strategies that meet those needs.

The potential benefits of weather information integration in TMC operations can be substantial. These include a more proactive approach to operations and maintenance that will lead to safer travel, better information for both highway operators and travelers, reduced operating costs, more efficient and cost-effective use of resources (labor, materials, equipment), better coordination among agencies, and more effective operational decision making.

This self-evaluation and planning guide will lead you (TMCs) through the following steps:

- Identify the relevant weather events in your jurisdiction.
- Determine the type and magnitude of impacts these events have on your transportation system, and hence on TMC operations and traffic management responsibilities.
- Identify your current strategies for managing the impacts of weather on your operations.
- Prioritize your needs for weather information application and integration.
- Identify integration strategies and solutions that are best suited to meeting your high priority needs.

The results of this self-evaluation will serve as input to guide the preparation of your weather integration plan. The strategies for integration of weather information appropriate to address TMC needs are not intended to imply FHWA standards or requirements; rather, the guide offers solution strategies as options to consider as you plan for future weather integration. The weather integration plan will provide the TMC a clear roadmap for incorporating weather information in various operational activities and decision-making.

Moreover, the self-evaluation is not intended to rate your current program or compare it with other programs but rather to enable identification of potential methods for integrating weather information into your TMC operations. The evaluation should not be used to compare programs and does not report scores or ratings in any way.

Organization of the Guide

The process to conduct the TMC self-evaluation and develop a plan for weather integration is presented as three major parts in the Guide as follows:

Part I. Self Evaluation

Part II. Guidance for Weather Integration

Part III. Development of a Weather Integration Plan

The steps or components of each part are illustrated in Figure 1.

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

Part I of the 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 Guide consists of two sections:

- Section 5 – This section 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 Guide provides guidance on developing a typical weather integration plan. A sample outline for an integration plan is included.

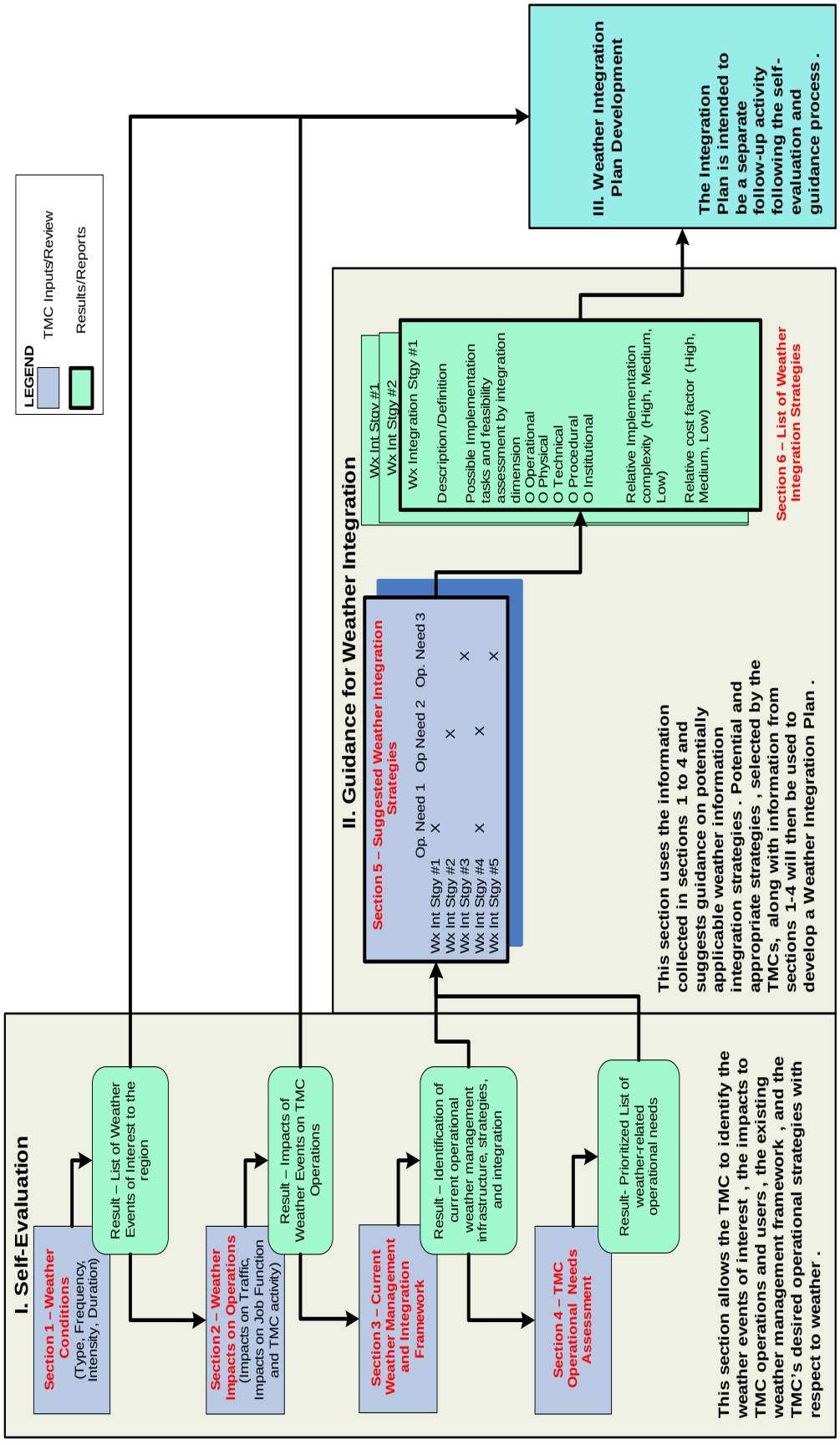

Figure 1 – Self-Evaluation and Planning Guide Organization

Completing the Self-Evaluation and Planning Process

An electronic version of the Guide was developed and will be distributed as a companion to this document. It is recommended that the TMC utilize this database tool to conduct the self-evaluation and use the manual Guide as reference throughout the process.

There are four steps that a TMC will follow to achieve a completed integration plan:

- Step 1: Preparing for the Self-Evaluation
- Step 2: Conducting the Self-Evaluation
- Step 3: Assessing and selecting weather integration strategies
- Step 4: Preparing the Integration Plan

Each step is described in greater detail below.

Step 1: Preparing for the Self-Evaluation

The following activities are recommended:

- Identify a lead TMC person to be the champion for this effort.
- Identify the self-evaluation team comprised of various stakeholders within and outside the TMC. Before initiating the self-evaluation process, identify the individuals in your TMC organization and other local agencies who are best positioned and experienced to address the steps outlined above, and involve them throughout the process. The lead person will assemble the appropriate evaluation team to participate in the activity. The evaluation team may include staff responsible for:
    - TMC center operations
    - TMC field and roadside operations
    - Public safety and emergency management
    - Weather information
    - Technology and systems integration
    - Maintenance and construction operations
- Plan and schedule meetings.

Step 2: Conducting the Self-Evaluation

- Using the guide, the evaluation team will proceed through the steps to complete their self-evaluation using the **database tool**.
- Identify a facilitator for the meetings and nominate staff to document the discussions during the self-evaluation

Step 3: Assessing and selecting weather integration strategies

- The evaluation team will review the results of the self-evaluation and the guidance that will include several candidate weather integration strategies that are suitable for meeting the high priority weather integration needs of the TMC.

The results from the self-evaluation will provide the input for preparing a Weather Integration Plan.

Step 4: Preparing the Weather Integration Plan

- The TMC will develop the Weather Integration Plan in consultation with the self-evaluation team and make any adjustments required to tailor the plan for their TMC.

PART I.

SELF-EVALUATION

Section 1: Weather Conditions

The objective of this first section is to identify what weather events occur most frequently and impact traffic conditions in your region. There are many different types of weather events that can occur across the country, but only some of these are likely to be of importance to your TMC operations.

This section is not intended to collect detailed climatology information about your region. Rather, the information collected will help narrow the focus to those weather events that impact TMC operations. In the **database-version**, only the weather events selected in question 1-1 below will carry forward to the other questions in Section 1 as well as subsequent sections of the Guide. In addition, this subset of weather events will be used to provide the appropriate local context for your TMC as you develop the weather integration plan.

Self-Evaluation Questions

1.1 What types of weather events occur in your region and how frequently do you experience them? If a weather event is not listed, please add it to the end of the list (in the blank cells) and specify the frequency of the weather event. Weather definitions are provided in Appendix A.

Note: Never The weather event does not occur in the region
Rare Once in two-three years
Seldom Once or twice a season
Occasional 3 to 5 times a season
Regular More than 10 times during a typical season

Weather Event	Never	Rare	Seldom	Occasional	Regular
Drizzle and Light Rain	☐	☐	☐	☐	☐
Moderate to Heavy Rain	☐	☐	☐	☐	☐
Sleet, and Freezing Rain	☐	☐	☐	☐	☐
Thunderstorms with rain	☐	☐	☐	☐	☐
Severe Thunderstorms	☐	☐	☐	☐	☐
Flooding	☐	☐	☐	☐	☐
Flurries and Light Snow	☐	☐	☐	☐	☐
Moderate to Heavy Snow	☐	☐	☐	☐	☐
Blizzard	☐	☐	☐	☐	☐
Blowing Snow	☐	☐	☐	☐	☐
High Winds	☐	☐	☐	☐	☐
Blowing Sand or Dust	☐	☐	☐	☐	☐
Smoke, Mist, Fog, Smog or Haze	☐	☐	☐	☐	☐
Bridge Frost, Road Frost	☐	☐	☐	☐	☐
Tornadoes	☐	☐	☐	☐	☐
Tropical Storms and Hurricanes	☐	☐	☐	☐	☐

Temperature Extremes	☐	☐	☐	☐	☐
Others (please specify)	☐	☐	☐	☐	☐

1.2 For the weather events that you identified above, to what geographic extent would you classify their impacts on traffic operations in your region?

Weather Event	Local/Isolated Spots	Corridor-Wide	Region/ Regional	State-wide
Drizzle and Light Rain	☐	☐	☐	☐
Moderate to Heavy Rain	☐	☐	☐	☐
Sleet, and Freezing Rain	☐	☐	☐	☐
Thunderstorms with rain	☐	☐	☐	☐
Severe Thunderstorms	☐	☐	☐	☐
Flooding	☐	☐	☐	☐
Flurries and Light Snow	☐	☐	☐	☐
Moderate to Heavy Snow	☐	☐	☐	☐
Blizzard	☐	☐	☐	☐
Blowing Snow	☐	☐	☐	☐
High Winds	☐	☐	☐	☐
Blowing Sand or Dust	☐	☐	☐	☐
Smoke, Mist, Fog, Smog or Haze	☐	☐	☐	☐
Bridge Frost, Road Frost	☐	☐	☐	☐
Tornadoes	☐	☐	☐	☐
Tropical Storms and Hurricanes	☐	☐	☐	☐
Temperature Extremes	☐	☐	☐	☐

1.3 To what extent do the weather events usually impact the traffic flow on your highway system? Impacts on traffic flow include increased travel times, increased crash risk, low visibility and disruption of vehicle operations.

Weather Event	No Impact	Little Impact	Moderate Impact	Significant Impact
Drizzle and Light Rain	☐	☐	☐	☐
Moderate to Heavy Rain	☐	☐	☐	☐
Sleet, and Freezing Rain	☐	☐	☐	☐
Thunderstorms with rain	☐	☐	☐	☐
Severe Thunderstorms	☐	☐	☐	☐
Flooding	☐	☐	☐	☐
Flurries and Light Snow	☐	☐	☐	☐
Moderate to Heavy Snow	☐	☐	☐	☐
Blizzard	☐	☐	☐	☐
Blowing Snow	☐	☐	☐	☐
High Winds	☐	☐	☐	☐
Blowing Sand or Dust	☐	☐	☐	☐
Smoke, Mist, Fog, Smog or	☐	☐	☐	☐

Haze				
Bridge Frost, Road Frost	☐	☐	☐	☐
Tornadoes	☐	☐	☐	☐
Tropical Storms and Hurricanes	☐	☐	☐	☐
Temperature Extremes	☐	☐	☐	☐

Section 2: Weather Impacts on TMC Operations

Weather often impacts the activities of individuals and agencies working to maintain safety and mobility of the transportation system. Making sense of weather information along with recognizing the benefits of its application beyond the simplest case is not a trivial task. As a generalization, TMC operators tend to take action based on their observations of traffic impacts rather than responding directly to available weather information. It is important to understand the nature of weather impacts on capacity and speed reductions, on safety (e.g., crash risk/frequency, incident management including Safety Service Patrols that are often dispatched from or coordinated with TMCs), and on institutional coordination (i.e., need for communication between traffic managers and maintenance, emergency management, and law enforcement personnel) to ensure that the self-evaluation and the integration solutions address the right concerns. The ability to estimate impacts could presumably lead to managing freeway and arterial systems more efficiently using advisory, control, and treatment strategies.

The previous section identified all the weather events of interest to the region and the TMC. This section focuses on identifying the impacts of these weather events *on your TMCs traffic operations*. Consider impacts on both the transportation system users and operators.

Self-Evaluation Questions

2.1 For the weather events that you identified above, which traffic impacts are commonly associated with the weather events in your region? If the impact is not listed, list the key traffic impact of concern in the space below.

Weather Event	Increased Travel Times	Increased Crash Risk	Reduced Roadway Capacity	Traffic Management Device Impairment (signal outages, lane control, etc)	Disruption of Commercial or Other Specialized Vehicle Operations	Road Closures	Other (Please Specify)
Drizzle and Light Rain	☐	☐	☐	☐	☐	☐	☐
Moderate to Heavy Rain	☐	☐	☐	☐	☐	☐	☐
Sleet, and Freezing Rain	☐	☐	☐	☐	☐	☐	☐
Thunderstorms with rain	☐	☐	☐	☐	☐	☐	☐
Severe Thunderstorms	☐	☐	☐	☐	☐	☐	☐
Flooding	☐	☐	☐	☐	☐	☐	☐
Flurries and Light Snow	☐	☐	☐	☐	☐	☐	☐
Moderate to Heavy Snow	☐	☐	☐	☐	☐	☐	☐
Blizzard	☐	☐	☐	☐	☐	☐	☐
Blowing Snow	☐	☐	☐	☐	☐	☐	☐
High Winds	☐	☐	☐	☐	☐	☐	☐
Blowing Sand or Dust	☐	☐	☐	☐	☐	☐	☐
Smoke, Mist, Fog, Smog or Haze	☐	☐	☐	☐	☐	☐	☐
Bridge Frost, Road Frost	☐	☐	☐	☐	☐	☐	☐
Tornadoes	☐	☐	☐	☐	☐	☐	☐
Tropical Storms and	☐	☐	☐	☐	☐	☐	☐

Hurricanes							
Temperature Extremes	☐	☐	☐	☐	☐	☐	☐

Other Impacts (Please specify by weather event)

Weather Event	Impact to Traffic

2.2 What roadway impacts are commonly associated with the weather events? Roadway impacts are effects of weather events effect on the transportation system. If there are other roadway impacts, please list them in the "other" column.

Weather Event	Slick Roads	Road Obstruction/ Submersion	Structural Damage to Facilities	Presence of Debris	Low Visibility	Other (Please Specify)
Drizzle and Light Rain	☐	☐	☐	☐	☐	☐
Moderate to Heavy Rain	☐	☐	☐	☐	☐	☐
Sleet, and Freezing Rain	☐	☐	☐	☐	☐	☐
Thunderstorms with rain	☐	☐	☐	☐	☐	☐
Severe Thunderstorms	☐	☐	☐	☐	☐	☐
Flooding	☐	☐	☐	☐	☐	☐
Flurries and Light Snow	☐	☐	☐	☐	☐	☐
Moderate to Heavy Snow	☐	☐	☐	☐	☐	☐
Blizzard	☐	☐	☐	☐	☐	☐
Blowing Snow	☐	☐	☐	☐	☐	☐
High Winds	☐	☐	☐	☐	☐	☐
Blowing Sand or Dust	☐	☐	☐	☐	☐	☐
Smoke, Mist, Fog, Smog or Haze	☐	☐	☐	☐	☐	☐
Bridge Frost, Road Frost	☐	☐	☐	☐	☐	☐
Tornadoes	☐	☐	☐	☐	☐	☐
Tropical Storms and Hurricanes	☐	☐	☐	☐	☐	☐
Temperature Extremes	☐	☐	☐	☐	☐	☐

Other Impacts (Please specify by weather event)

Weather Event	Impact to Traffic

2.3 How do the weather events specifically impact your TMC operations? These operations only pertain to resources, labor, and equipment that are controlled and operated by the TMC and not the entire transportation department. (If there are other changes to TMC operations and functions, list them in the "other" column).

Weather Event	Increased Use of Equipment/ Materials	Increased In-house Labor/ (both center and field)	Increased Contractor Labor	Loss of Communi-cations/ Power	Changes in Traffic Control Operations	Other Significant Impacts (Please Specify)
Drizzle and Light Rain	No Impacts	No Impacts	No Impacts	No Impacts	No Impacts	
Moderate to Heavy Rain	No Impacts	No Impacts	No Impacts	No Impacts	No Impacts	
Sleet, and Freezing Rain	No Impacts	No Impacts	No Impacts	No Impacts	No Impacts	
Thunderstorms with rain	No Impacts	No Impacts	No Impacts	No Impacts	No Impacts	
Severe Thunderstorms	No Impacts	No Impacts	No Impacts	No Impacts	No Impacts	
Flooding	No Impacts	No Impacts	No Impacts	No Impacts	No Impacts	
Flurries and Light Snow	No Impacts	No Impacts	No Impacts	No Impacts	No Impacts	
Moderate to Heavy Snow	No Impacts	No Impacts	No Impacts	No Impacts	No Impacts	
Blizzard	No Impacts	No Impacts	No Impacts	No Impacts	No Impacts	
Blowing Snow	No Impacts	No Impacts	No Impacts	No Impacts	No Impacts	
High Winds	No Impacts	No Impacts	No Impacts	No Impacts	No Impacts	
Blowing Sand or Dust	No Impacts	No Impacts	No Impacts	No Impacts	No Impacts	
Smoke, Mist, Fog, Smog or Haze	No Impacts	No Impacts	No Impacts	No Impacts	No Impacts	
Bridge Frost, Road Frost	No Impacts	No Impacts	No Impacts	No Impacts	No Impacts	
Tornadoes	No Impacts	No Impacts	No Impacts	No Impacts	No Impacts	
Tropical Storms and Hurricanes	No Impacts	No Impacts	No Impacts	No Impacts	No Impacts	
Temperature Extremes	No Impacts	No Impacts	No Impacts	No Impacts	No Impacts	

Section 3: Current Weather Management and Integration Framework

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 the identification of both concepts, or items of integration, by which effective and optimal integration may occur, and the methods that show how the concepts can be realized and effectively implemented.

These items or 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. Several broad concepts of weather integration and associated methods to achieve these concepts are discussed in the precursor document to this Guide titled Integration of Emergency and Weather Elements into Transportation Management Centers: Final Report[1]. These broad concepts present a wide variety of ways in which weather information can be integrated into your TMC operations ranging from improved awareness of weather to making the TMC the focal point for weather information.

Levels of integration reflect an action that builds upon an item of integration and describes how a particular item of integration can be achieved. Applying a level of integration to achieve an item of integration requires the full spectrum of assessment, planning, and implementation strategies. For some strategies, the effort involves the procurement of services that support more effective utilization of available weather data within the TMC. For some strategies, implementation could involve the use of custom surface transportation weather services that provide notification of specific road weather[2] hazards at discrete short time intervals that address defined support requirements for the TMC. Others strategies could actively integrate weather and traffic management through the development of sophisticated new products that use computer modeling of traffic volumes by incorporating short-range, site-specific weather predictions of the roadway environment. Other strategies may result in a growth in personnel commitments within the TMC to routinely facilitate the incorporation, analysis, and exchange of weather information with other operational aspects of the TMC.

The current weather information framework of a TMC can be characterized or described using 11 items of integration as follows:

- Use of Internal Weather Information Resources

[1] FHWA, *Integration of Emergency and Weather Elements into Transportation Management Centers*, Final Report, February 2006.

[2] Weather integration within TMC operations incorporates content from both commonly used weather observations and from a more application-specific transportation content commonly referred to as "road weather." A reference to *road weather* typically also includes many of the general weather elements found in other weather-related applications, such as weather radar, weather satellite, or weather prediction models, but most frequently those involving surface weather conditions, such as pavement temperature. Referencing *weather* within transportation results in ambiguity as to whether the elements and/or conditions being referenced are specific to road weather or independent of road weather. Therefore, in this report a reference to "weather" implies conditions and elements not dependent upon the roadway environment, and a reference to "road weather" includes weather-related conditions and elements in a roadway environment and related elements that are external to the roadway environment.

- 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 Meteorologists
- Alert Notification
- Decision Support
- Weather/Road Weather Data Acquisition

These items represent both the state-of-the-art practice as well as the best practices observed at various TMCs around the country as determined from the prior weather integration study.

For each item of integration, five different levels of integration are identified. Table 3.1 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.

Increasing integration need not only mean going to the next level or adding new levels to various items of integration. It can also occur when expanding existing levels of integration to new locations under TMC jurisdiction.

In order to make recommendations regarding future weather integration solutions, it is important to understand what your TMC currently has in place and your current level of weather integration. The questions in the self-evaluation are intended to determine the various levels your TMC has reached across all 11 items of integration.

Table 3.1. Items of Integration

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 Road Weather Information Systems (RWIS) and related networks	Level 3 data plus data from Automatic Vehicle Locations/Mobile Data Computers (AVL/MDC) sources and internal radio communications	Level 4 data with addition of analyzed fields and transformed data parameters (frost index, wind chill, est. snow, ice, water depth)
Use of External Weather Information Sources	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

Item of Integration (Broad Requirement/Concept)	**Levels of Integration**					
	None	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**
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 3.1. Items of Integration (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 scenarios through software supply potential solutions with projected outcomes based	Automated condition recognition and advisory or control strategy presented to	Automated condition recognition and advisory or control strategy implemented

Item of Integration (Broad Requirement/Concept)	Levels of Integration					
	None	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**
			response	on weather / traffic modeling	operator for acceptance into ATMS	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

Self-Evaluation Questions

3.1 Please select the statement(s) below that closely reflect(s) your CURRENT USE OF INTERNAL WEATHER INFORMATION RESOURCES. Check all those that apply.

Level	Statement	Check Applicable Statements
	None	☐
1	Camera imagery	☐
2	Radar, satellite, ASOS and AWOS data, and general zone-type forecast information	☐
3	Level 2 data plus data from Road Weather Information Systems (RWIS) and related networks	☐
4	Level 3 data plus data from Automatic Vehicle Location/Mobile Data Computers (AVL/MDC) sources and internal radio communications	☐
5	Level 4 data with addition of analyzed fields and transformed data parameters (frost index, wind chill, est. snow, ice, water depth)	☐

3.2 Please select the statement(s) below that closely reflect(s) your CURRENT USE OF EXTERNAL WEATHER INFORMATION RESOURCES. Check all those that apply.

Level	Statement	Check Applicable Statements
	None	☐
1	General weather information, forecasts, and interpretation provided through media as irregular service (radio and TV weather)	☐
2	Internet provided, public access general forecasts, weather radar or satellite image or weather-specific broadcast channel	☐
3	Field observers or probes providing scheduled weather / driving condition information from entire route system	☐
4	Contractor provided surface transportation weather forecasts targeted at the operational needs of the TMC agencies	☐
5	Direct connection between private weather information service providers and traffic management software	☐

3.3 Please select the statement(s) below that closely reflect(s) your CURRENT status relating to the AVAILABILITY OF WEATHER INFORMATION. Check all those that apply.

Level	Statement	Check Applicable Statements

	None	☐
1	Cable channel or subscription weather information vendor providing general weather information	☐
2	Internet provided weather radar or satellite image on video wall	☐
3	Field observers or ESS network providing scheduled road or driving condition reports	☐
4	Vendor provided daily surface transportation weather forecasts and observed weather conditions including Level 3	☐
5	Meteorologist, located within TMC, forecasting and interpreting weather	☐

3.4 Please select the statement(s) below that closely reflect(s) your CURRENT FREQUENCY OF USE OF WEATHER FORECASTS. Check all those that apply.

Level	Statement	Check Applicable Statements
	None	☐
1	Receive information of weather forecasts on a request basis	☐
2	Receive weather forecast once daily.	☐
3	Receive periodic forecasts several times a day	☐
4	Receive hourly updates of weather forecasts several times a day	☐
5	Receive continuous updates of weather forecasts in real-time	☐

3.5 Please select the statement(s) below that closely reflect(s) your CURRENT FREQUENCY OF USE WEATHER/ROAD WEATHER OBSERVATIONS. Check all those that apply.

Level	Statement	Check Applicable Statements
	None	☐
1	Receive information of weather conditions on a request basis	☐
2	Receive weather observations once hourly	☐
3	Level 2 plus receive weather/road weather observations when predefined thresholds have been exceeded	☐
4	Receive weather/road weather observations every ten minutes and when predefined thresholds have been exceeded	☐
5	Receive weather/road weather observations continuously with data above predefined thresholds highlighted	☐

3.6 Please select the statement(s) below that closely reflect(s) your CURRENT STATUS OF WEATHER INFORMATION COORDINATION. Check all those that apply.

Level	Statement	Check Applicable Statements
	None	☐
1	Intra-TMC committee tasked with weather information coordination	☐
2	Identified TMC or maintenance staff member tasked with coordinating weather information at TMC or virtually linked with TMC	☐
3	Dedicated weather operations supervisor	☐
4	Meteorology staff located within the TMC forecasting and interpreting weather information	☐
5	Co-location of the Emergency Operations Center (EOC)/Office of Emergency Management (OEM)	☐

3.7 Please select the statement(s) below that closely reflect(s) your CURRENT EXTENT OF COVERAGE. Check all those that apply.

Level	Statement	Check Applicable Statements
	None	☐
1	Sparse Set of Isolated Locations	☐
2	Network of Scattered Locations	☐
3	Corridor-level	☐
4	Multiple-corridor/sub-regional	☐
5	Regional/Statewide	☐

3.8 Please select the statement(s) below that closely reflect(s) your CURRENT INTERACTION WITH METEOROLOGISTS. Check all those that apply.

Level	Statement	Check Applicable Statements
	None	☐
1	Focus group or informal gatherings of local professionals from the transportation management and weather communities	☐
2	Develop check list of routine weather awareness activities	☐
3	Periodic staff meeting that includes a meteorologist to discuss weather information needs and responses	☐
4	With a meteorologist present conduct post-event debriefing / regular assessment to fine-tune responses	☐
5	Daily personal briefings and integrated interruptions by meteorology staff within the TMC	☐

3.9 Please select the statement(s) below that closely reflect(s) your CURRENT ALERT NOTIFICATION systems. Check all those that apply.

Level	Statement	Check Applicable Statements
	None	☐
1	Monitor media outlet, Internet page, or data stream for critical events	☐
2	Telephone call list	☐
3	Manual email/paging system	☐
4	Automated TMC road weather system-generated notifications (e.g., Email or page from Road Weather Information System or Flood Early Warning System)	☐

5	Automatic notification through Center-to-Center communications	☐

3.10 Please identify select the statement(s) below that closely reflect(s) your CURRENT USE OF DECISION SUPPORT. Check all those that apply.

Level	Statement	Check Applicable Statements
	None	☐
1	Ad-hoc implementation of weather management strategies	☐
2	Use quick-reference flip cards on operator's workstation to implement predefined response	☐
3	Response scenarios through software supply potential solutions with projected outcomes based on weather / traffic modeling	☐
4	Automated condition recognition and advisory or control strategy presented to operator for acceptance into ATMS	☐
5	Automated condition recognition and advisory or control strategy implemented without operator intervention	☐

3.11 Please select the statement(s) below that closely reflect(s) your CURRENT WEATHER/ROAD WEATHER DATA ACQUISITION methods. Check all those that apply.

Level	Statement	Check Applicable Statements
	None	☐
1	Media Reports	☐
2	Internet and/or Satellite Data Sources	☐
3	Across agency intranet and dedicated phone acquisition	☐
4	Dedicated communications link to state, federal, and private data sources	☐
5	Dedicated communications link to state, federal, and private data sources including vehicle-derived weather data	☐

Section 4: TMC Operational Needs Assessment

Previous studies have shown that the integration of data and information across multiple agencies and organizations is beneficial to a TMC to the extent that it allows the TMC to conduct its operations more effectively.[3] The sharing and exchange of weather information also provide an opportunity to bring together agencies or elements within a given agency more effectively.

Understanding the context in which weather information will be used is critical in determining an appropriate integration strategy. Given that weather integration is a relatively new field and TMCs are more likely to be aware of their operational needs, it is important here to identify a comprehensive list of TMC operational needs for weather management. These needs can then be prioritized and related to weather information and integration solutions.

Operational needs are identified in the following five categories:

- Weather information gathering – Obtaining better weather data and information
- Institutional coordination – Coordination within and outside a TMC
- Advisory functions – Advisory functions of a TMC during a weather event. Advisory strategies provide information on prevailing and predicted conditions to both transportation managers and motorists.
- Control functions – Control functions of a TMC during a weather event. Control strategies alter the state of roadway devices to permit or restrict traffic flow and regulate roadway capacity.
- Treatment functions – Treatment functions of a TMC during a weather event. Treatment strategies supply resources to roadways to minimize or eliminate weather impacts.

It is clear that weather has major and minor impacts on transportation management operations. More typically these are impacts that result in reduced traffic flow or increased traffic incidents. Extreme weather events like hurricanes and blizzards typically cause the greatest disruption to transportation systems. These events typically result in major routing changes, dramatic traffic bottlenecks, or a complete urban, statewide, or regional transportation system shutdown.

Section 2 identified the impacts of the weather events on TMC operations, while Section 3 characterizes the existing framework of the TMC based on 11 items of integration. In responding to the questions below pertaining to the Operational Needs of your TMC, it is recommended that you review your responses in the previous sections regarding the nature and frequency of the weather events, their impacts on the system, the users, and TMC operations, and the current levels of weather integration in your agency.

[3] FHWA, *Integration of Emergency and Weather Elements into Transportation Management Centers*, Final Report, February 2006.

Self-Evaluation Questions

4.1. Rank each of the following weather information needs in terms of its priority to your TMC. The choices are none, low, moderate or high priority. While ranking the needs, consider current and desired weather management framework and priorities.

Need	0 None	1 Low	2 Moderate	3 High
Better short-term forecasts of arrival time, duration, and intensity of specific weather events at specific locations	☐	☐	☐	☐
Better prediction of impact of weather events including assessment of reductions in capacity	☐	☐	☐	☐
Better real-time information on road conditions during weather events	☐	☐	☐	☐
Improve the coverage and granularity of weather information in the region	☐	☐	☐	☐
Assistance in interpreting weather information and how best to adjust operations in light of that information	☐	☐	☐	☐

4.2. Rank each of the following institutional coordination needs in terms of its priority to your TMC. The choices are none, low, moderate or high priority. While ranking the needs, consider current and desired weather management framework and priorities.

Need	0 None	1 Low	2 Moderate	3 High
Develop and implement clear, written policies and procedures for handling weather events	☐	☐	☐	☐
Improve coordination within the TMC	☐	☐	☐	☐
More coordinated responses and information with adjacent jurisdictions/regions	☐	☐	☐	☐
Improve coordination with local public safety and emergency agencies	☐	☐	☐	☐
More opportunities and mechanisms for communications and exchange with others in the weather community and those with experience dealing with weather events	☐	☐	☐	☐

4.3. Rank each of the following advisory operations needs in terms of its priority to your TMC. The choices are none, low, moderate or high priority. While ranking the needs, consider current and desired weather management framework and priorities.

Need	0 None	1 Low	2 Moderate	3 High
Disseminate weather information to a larger set of stakeholders and users in the region (including transit and other modes)	☐	☐	☐	☐
Improve message content (for DMS, 511, HAR, Web sites, etc.)	☐	☐	☐	☐
Improve targeting of weather messages (site-specific; user group specific) to more effectively convey road weather information.	☐	☐	☐	☐
Provide better pre-trip weather condition information to aid travelers in their decision-making	☐	☐	☐	☐
Provide better en-route information on weather conditions to aid travelers in their decision-making	☐	☐	☐	☐

4.4. Rank each of the following traffic control operations needs in terms of its priority to your TMC. The choices are none, low, moderate or high priority. While ranking the needs, consider current and desired weather management framework and priorities.

Need	0 None	1 Low	2 Moderate	3 High
Improve management of emergency routing and evacuation for large-scale weather events	☐	☐	☐	☐
Improve traffic diversion and alternate routing capabilities	☐	☐	☐	☐
Improve safety at intersections during weather events	☐	☐	☐	☐
Improve traffic signal timing during weather events to facilitate traffic movement	☐	☐	☐	☐

4.5. Rank each of the following treatment operations needs in terms of its priority to your TMC. The choices are none, low, moderate or high priority. While ranking the needs, consider current and desired weather management framework and priorities.

Need	0 None	1 Low	2 Moderate	3 High
Improve maintenance decision-making by determining the optimal treatment materials, application rates, and timing of treatments	☐	☐	☐	☐
Improve the timeliness of weather management response including deployment of field personnel and equipment	☐	☐	☐	☐
Reduce the time required to restore pre-event level of service operations after a weather event	☐	☐	☐	☐

Reduce costs of roadway treatment options	☐	☐	☐	☐

PART II.

PLANNING AND GUIDANCE

Section 5: Suggested Weather Integration Strategies

This section builds on the responses to the self-evaluation in Part I (Sections 1 through 4). The previous sections of the Guide addressed the major weather conditions in the region, their impacts on traffic flow and traffic operations, the current use of weather information in the TMC, and the critical operational needs of the TMC with respect to weather.

Section 5 provides guidance on how to identify the integration strategies and solutions that are best suited to meet the high priority needs of the TMC. The process is intended to:

- Address identified operational needs (from Section 4)
- Account for the operational environment and existing level of weather integration (from Sections 1 through 3)
- Allow a structured pathway towards meeting the operational needs

The key feature in this section of the guide is the linkage between TMC operational needs and weather integration strategies. While creating this matrix, the following process was used:

- Map the Item(s) of Integration required to the need(s) identified by the TMC
- Identify the lowest level of integration that can address the needs, given that:
    - One need may require several items of integration
    - One item of integration may address several needs

The selection of appropriate strategies can be accomplished in several different ways, depending upon which need the evaluation team is trying to address. Two possible scenarios are described below:

1. For a subset of needs – If your TMC would like to identify a comprehensive list of weather integration strategies for a particular need or set of needs. This would be appropriate if your agency is attempting to solve a particular need.

2. For all critical needs – If your TMC wants to identify all strategies for the critical needs. This would identify all the potential strategies the TMC can implement to meet those critical needs.

For each scenario, the selection of appropriate strategies is based on the difference between the TMCs existing weather integration level and the level required to meet a particular need. The process of matching needs to weather integration levels is internally programmed for the **database-version** of the guide. However, from a process standpoint, the following steps are involved in selection of the strategies based on the needs:

- Step 1 – The current levels of integration in Table 3.1 are identified based on responses to Section 3 (see Table 5.2)
- Step 2 – The needs identified from Section 4 are prioritized (high, medium, low)
- Step 3 – For each need or collection of needs, the minimum level of integration across the items required to reasonably address the need is identified using the needs vs. items of

integration matrix Table 5.1), and compared to the existing conditions. (Tables 5.3 and 5.4)

- Step 4 - The differences between the current levels and the levels required by the needs provide a list of appropriate strategies for a TMC to pursue for each need. (see Table 5.5)

The process is illustrated graphically through a sample application in the following pages. The outcome from this process is a potential list of weather integration strategies.

These lists of strategies do not represent the solution. As TMC conditions, roles, and responsibilities are unique, the evaluation team needs to evaluate the strategies for their suitability to the TMC by reviewing the details of each strategy.

To review the strategies in detail, Section 6 allows the team to select a subset of strategies and evaluate its applicability.

In summary, when using the **database-version** of the Guide, the following actions and responses will be required.

1. The TMC Evaluation Team will be asked to select a need, a set of needs, or just their critical needs.

2. The Guide will present the TMC Evaluation Team with possible integration strategies that address their selected need(s).

3. The TMC Evaluation Team will be asked to select the strategy, or set of strategies, that they think are most suited to their conditions. The team can also select intermediate strategies, which might not address the needs completely but may be more feasible currently.

4. These selected strategies will be carried forward to Section 6, where additional information will be provided to assist with the development of the Integration Plan.

Table 5.1 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 5.1 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

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
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

Table 5.2 Sample Application of the Matrix Using Results of Section 3 (Current Status is in Bold, Italic, Yellow Highlight)

Item of Integration (Broad Requirement)	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 AVL/MDC sources and internal radio communications	Level 4 data with addition of analyzed fields and transformed data parameters (frost index, wind chill, est. snow, ice, water depth)
Use of External Weather Information Sources	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

Item of Integration (Broad Requirement)	Levels of Integration					
	None	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**
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
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 outlet, Internet page, or data stream for critical events***	Telephone call list	Manual email/paging system	TMC road weather system (RWIS / ALERT / FEWS) generated specific notifications (Email or page)	Automatic notification through Center-to-Center communications

Table 5.2 Sample Application of the Matrix Using Results of Section 3 (Current Status is in Bold, Italic, Yellow Highlight) (continued)

Item of Integration (Broad Requirement)	Levels of Integration					
	None	Level 1	Level 2	Level 3	Level 4	Level 5
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

Table 5.3 Identify Critical Need in the Needs vs. Integration Item matrix (from Table 5.1)*

* Row in Bold Text / Box, Pink Highlight is identified as critical need in Section 4. Numbers indicate the levels of integration at which this need can be implemented.

Needs/Integration Mapping(Numbers indicate the level of integration at which this need can be reasonably addressed)	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	

Table 5.4 Current Status is in Bold, Italic, Yellow Highlight - Level Required to Address Critical Need in Bold Text / Box, Pink Highlight (from Table 5.3)

Item of Integration (Broad Requirement)	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 AVL/MDC sources and internal radio communications	Level 4 data with addition of analyzed fields and transformed data parameters (frost index, wind chill, est. snow, ice, water depth)
Use of External Weather Information Sources	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
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

Item of Integration (Broad Requirement)	Levels of Integration					
	None	Level 1	Level 2	Level 3	Level 4	Level 5
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 outlet, Internet page, or data stream for critical events***	Telephone call list	Manual email/paging system	**TMC road weather system (RWIS / ALERT / FEWS) generated specific notifications (Email or page)**	Automatic notification through Center-to-Center communications

Table 5.4 Current Status is in Bold, Italic, Yellow Highlight - Level Required to Address Critical Need in Bold Box, Pink Highlight (from Table 5.3) (continued)

Item of Integration (Broad Requirement)	Levels of Integration					
	None	Level 1	Level 2	Level 3	Level 4	Level 5
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

Table 5.5 Suggested Strategies for Critical Need

Critical Need 1 - Better prediction of impact of weather events including assessment of reductions in capacity

Item(s) of Integration	Current Stage (where TMC is now)	Possible Intermediate Stage(s)	Required to Address the Need
Use of Internal Weather Information Sources	None	Radar, satellite, ASOS and AWOS data, and general zone-type forecast information	Intermediate data plus data from RWIS and related networks
Use of External Weather Information	General weather information, forecasts, and interpretation provided through media as irregular service (radio and TV weather	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
Availability of Weather Information	Cable channel or subscription weather information vendor providing general weather information	Internet provided weather radar or satellite image on video wall Field observers or ESS network providing scheduled road or driving condition reports	Vendor provided daily surface transportation weather forecasts and observed weather conditions including Level 3
Frequency of Weather Forecasts	Receive information of weather forecasts on a request basis	Receive weather forecast once daily.	Receive periodic forecasts several times a day
Frequency of Road Weather Information	Receive information of road weather conditions on a request basis	Receive road weather observations once hourly	Level 2 plus receive weather/road weather observations when predefined thresholds have been exceeded
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
Extent of Coverage	Sparse set of locations	Network of scattered locations	Corridor-level
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
Alert Notification	Monitor media outlet, Internet page, or data stream for critical	Telephone call list Manual email/paging system	Automated TMC road weather system-generated notifications

	events	(e.g., Email or page from Road Weather Information System or Flood Early Warning System)

Section 6: List of Weather Integration Strategies

This section provides additional information to assist the TMC in moving towards the integration planning stage for the strategies identified in Section 5. The strategies are defined and grouped by item of integration. The relative levels of complexity and cost are also identified for the strategies.

Implementing any of the strategies imposes a variety of impacts and requirements on various aspects of TMC operations, procedures, and capabilities. In the previous study (Integration of Emergency and Weather Elements into Transportation Management Centers), five dimensions of integration were identified as important components of how a particular strategy might be implemented (see box below). Section 6 also identifies the steps a TMC must undertake in order to successfully achieve a specific level of integration that will meet their needs.

The overall extent of integration at any TMC can be described in terms of the following five dimensions:

- **Operational Integration.** The ways in which data and information are shared and used by TMCs and connected agencies, organizations, and systems to support traffic operations. Integrated control of traffic systems, and shared decision-making with regard to TMC traffic functions. The remaining four dimensions support operational integration.
- **Physical Integration.** The agencies, organizations, and systems physically linked or collocated for the purpose of sharing data or information in support of traffic operations.
- **Technical Integration.** The data and information communicated, exchanged, and shared through physical linkages among people, systems and organizations, both within a TMC and between a TMC and other entities. This data and information exchange can be achieved through a range of means from verbal exchanges to automated electronic exchanges and decision support systems that integrate available information to enhance operational efficiency and effectiveness.
- **Procedural Integration.** The development and use of policies, plans and procedures that support an integrated traffic operations in a TMC; the extent to which policies, plans and procedures are written down, made accessible to staff, reflect multi-agency interests and responsibilities, and are tested and reinforced with training and exercises; and, the coordination of policies, plans and procedures across integrated agencies and organizations.
- **Institutional Integration.** The level of commitment and partnership within and between participating organizations and agencies to achieve successful integration; leadership supporting the value of integration, and the willingness of partners to seek to collaborate to solve problems jointly; the clarity with which participant organizations' roles and responsibilities in support of integrated operations are spelled out and

understood; the vertical and horizontal collaboration within and between agencies and organizations in support of TMC traffic operations; and, agreements established among entities to support interaction and integration.

To learn more about any of the items of integration and strategies associated with them, follow the hyperlinks in Table 6.1 below or turn to the desired page:

Table 6.1 Items of Integration

6.1 Item of Integration – Use of Internal Weather Information Resources

This item pertains to the use of weather data and information resources that are available to the transportation agency and its personnel. Data/information are cumulative at increasing levels of integration given the logical progression of the data required. Resources could range from basic camera imagery to very sophisticated weather information processing and data collection.

6.1.1 Strategies (or Levels of Integration)

Level 1 – Camera imagery. Camera imagery will capture a basic assessment of weather conditions at one or more locations either continuously or as snapshots at a discrete time interval. Camera imagery can be used for now-casting activities but provides little information regarding conditions affecting traffic in the future. The camera images used can include, but are not limited to, traffic cameras, RWIS cameras, local/regional web-cams, and other camera imagery. Camera imagery is the basic level of weather information as it provides no assessment of conditions but relies on human interpretation to evaluate the current state of the atmosphere.

Level 2 – Radar, satellite, ASOS and AWOS data, and general zone-type forecast information, This level of integration will provide TMCs with data on a local, regional, and/or statewide scale(s). Radar and satellite will provide past and present data on possible precipitation over a designated region while ASOS and AWOS will provide observations of conditions at precise, pre-determined locations. General zone-type forecast information will give TMCs a broad picture of possible weather events that may affect their region. These types of forecasts will provide information on a regional scale, including expected:

- Maximum and minimum temperatures
- Average wind speed and direction
- Cloud cover
- Chance of precipitation within the region
- Range of timing associated with precipitation

Level 3 – Level 2 data plus data from Road Weather Information Systems (RWIS) and related networks. TMCs will utilize all data sets within Level 2 integration but also incorporate data from RWIS environmental sensor stations (ESS) and other weather networks that may be available for a given location. ESS will provide TMCs with weather directly adjacent to the road allowing for better understanding of weather conditions affecting the road surface and traffic flow. The ESS observations may include, but are typically limited to:

- Air temperature
- Relative humidity/dew point temperature
- Wind speed and direction
- Pavement surface temperature
- Pavement surface condition
- Chemical concentration or freeze point temperature

Level 4 – Level 3 data plus data from Automatic Vehicle Location (AVL) and Mobile Data Computer (MDC) sources and internal radio communications. AVL/MDC data provided within Level 4 integration will help TMCs assess the road conditions at present time. They also include valuable information on the type of treatment being applied to the roads along with the location of this chemical application. TMCs will be able to integrate this information in their traffic monitoring activities and reroute traffic when conditions warrant such action. Internal radio communications also will allow TMCs to be aware of upcoming maintenance actions along with up-to-date road conditions that are being observed by maintenance personnel. Internal radio communications can aid in quicker reaction time to adjust to the changing road conditions due to adverse weather.

Level 5 – Level 4 data with addition of analyzed fields and transformed data parameters (frost index, wind chill, estimated snow, ice, water depth). This level of integration represents the ultimate level of weather information resources that can be utilized by TMCs in their operations. Data collected within the previous levels of integration will be analyzed and transformed into weather products that will provide useful information for their daily operations.

6.1.2 Level of Complexity and Relative Costs

The following table describes the relative levels of complexity and cost within each level of integration for the weather information resources category.

Table 6.2 Relative Complexity and Cost of Implementing Different Levels for the Item of Integration – Use of Internal Weather Information Resources

Level of Integration	Description	Level of Complexity	Relative Cost
1	Camera imagery	Low	Medium
2	Radar, satellite, ASOS and AWOS data, and general zone-type forecast information	Low	Low
3	Level 2 data plus data from RWIS and related networks	Medium	Medium
4	Level 3 data plus data from AVL/MDC sources and internal radio communications	High	High
5	Level 4 data with addition of analyzed fields and transformed data parameters (frost index, wind chill, estimated snow, ice, water depth)	High	High

6.1.3 Requirements at Various Levels of Integration

Implementing any of the above strategies has a variety of impacts and requirements in each of the five dimensions of integration – Operational, Physical, Technical, Procedural, and Institutional. The table below identifies the steps a TMC must take to successfully achieve the specified levels of integration for each dimension of integration.

Table 6.3 Requirements Across Five Integration Dimensions and Levels for the Item of Integration – Use of Internal Weather Information Resources *

Operational Dimension	
Level 1	▪ Utilize existing camera resources to assess current weather conditions and their impact on traffic. ▪ Conduct staff training sessions on interpretation of imagery characteristics
Level 2	▪ Use radar, satellite, ASOS/AWOS, and NWS zone forecast data within the TMCs operations ▪ Conduct staff training sessions on the characteristics of these weather information resources
Level 3	▪ Use RWIS and related data within TMC operations ▪ Conduct staff training sessions on the features of RWIS data and how to interpret their impact on traffic flow
Level 4	▪ Use MDC data and information gained from radio communications in TMC operations ▪ Conduct staff training sessions on MDC data, its characteristics, and how to utilize in operations ▪ Discuss methods to more effectively integrate radio communications into routine traffic operations
Level 5	▪ Use analyzed weather data fields in TMC operations ▪ Conduct staff training sessions on the interpretation of the data fields and how they may be used to support traffic management decisions

Table 6.3 Requirements Across Five Integration Dimensions and Levels for the Item of Integration – Use of Internal Weather Information Resources *(continued)

Physical Dimension	
Level 1	▪ Acquire access to camera imagery both within and outside of the TMCs jurisdiction ▪ Establish communications links to gather all desired camera imagery ▪ Design and develop the database necessary to store data the camera imagery for the desired period of retention ▪ Develop or procure the display management system and the display devices to support TMCs imagery requirements
Level 2	▪ Establish the communications link to the weather resource data ▪ Procure any necessary equipment to process or display the weather data
Level 3	▪ Establish a communications link to a source of the RWIS data
Level 4	▪ Establish a communications link to a source of the MDC data
Level 5	▪ Establish a communications link to a source of the post-processed weather data
Technical Dimension	
Level 1	▪ Determine imagery sources and mechanism to retrieve or stream these images ▪ Determine data flow and devices to handle flow ▪ Establish specifications for equipment to handle image acquisition, storage, and display ▪ Develop or procure system to process imagery and display the requested images on operator's console or display screen(s)
Level 2	▪ Determine the source of the weather data ▪ Determine how the data will be processed internally ▪ Determine whether the data will be displayed separately from camera imagery or via the same display mechanism ▪ Develop or procure the necessary software to manage the data stream and permit operators to request and display the desired images or image loops
Level 3	▪ Determine the source of the RWIS and related data ▪ Determine how the data will be processed internally ▪ Determine whether the data will be displayed separately from camera imagery or via the same display mechanism ▪ Develop or procure the necessary software to manage the data stream and permit operators to request and display the data in the desired format
Level 4	▪ Determine the source of the MDC data ▪ Determine how the data will be processed internally ▪ Define and develop the data flow structure for AVL/MDC data into weather information system ▪ Determine whether the data will be displayed separately from camera imagery or via the same display mechanism ▪ Develop or procure the necessary software to manage the data stream and permit operators to request and display the desired images or image loops
Level 5	▪ Integrate analysis products into the infrastructure developed for the previous levels of integration

Table 6.3 Requirements Across Five Integration Dimensions and Levels for the Item of Integration – Use of Internal Weather Information Resources *(continued)

Procedural Dimension	
Level 1	▪ Establish procedures to report camera outages and/or display issues ▪ Establish procedures to restore camera operations and guidelines on processes, deadlines, and methods of monitoring progress/completion ▪ Establish public relations material on use of camera imagery in TMC
Level 2	▪ Define which ASOS/AWOS stations and zones are needed for operations ▪ Establish procedures to restore data feed and processing if a break in acquisition occurs ▪ Establish public relations material on use of weather information
Level 3	▪ Define which RWIS stations or other resources are necessary to support operations ▪ Establish procedures to restore RWIS data feed and processing if a break in acquisition occurs ▪ Establish public relations material on use of RWIS information
Level 4	▪ Define which maintenance routes should be sources of MDC data for operations ▪ Establish procedures to restore data feed and processing if a break in acquisition occurs ▪ Establish public relations material on use of weather and maintenance information from vehicles
Level 5	▪ Define which products need to be accessible in TMC ▪ Establish procedures to restore access to data if a break in acquisition occurs ▪ Establish public relations material on use of all levels of service and its benefit to TMC operations
Institutional Dimension	
Level 1	▪ Determine how management may acquire access to the camera imagery ▪ Establish rules of practice regarding use of camera imagery ▪ Map out methods for integration of weather-derived information from camera imagery into existing or planned traffic management programs
Level 2	▪ Determine how management may acquire access to the weather data ▪ Establish rules of practice regarding use of the weather data ▪ Map out methods for integration of the weather information into existing or planned traffic management programs
Level 3	▪ Determine how management may acquire access to the RWIS data ▪ Establish rules of practice regarding use of RWIS data ▪ Map out methods for integration of RWIS data into existing or planned traffic management programs
Level 4	▪ Determine how management may acquire access to the MDC data ▪ Establish rules of practice regarding use of MDC data ▪ Map out methods for integration of MDC data into existing or planned traffic management programs
Level 5	▪ Determine how management may acquire access to the entire suite of weather support information ▪ Establish rules of practice regarding use of the weather support data ▪ Map out methods for integration of the various weather resources into existing or planned traffic management programs

* For all dimensions, requirements are described for the level of integration to which they first apply. If requirements are not mentioned for a higher level(s), then the last level mentioned is adequate for all the higher levels.

6.2 Item of Integration – Use of External Weather Information Resources

This item pertains to the use of weather information resources generated by weather service providers external to the TMC or affiliated transportation agencies. This is usually a progression from a discrete level to a higher level and not necessarily an accumulation of all the individual components of the prior levels. The following strategies range from general forecasts to field observation and integration of external information with TMC software.

6.2.1 Strategies (or Levels of Integration)

Level 1 – General weather information, forecasts, and interpretation provided through media as an intermittent service (radio and TV weather). In this level of integration TMCs will rely solely on basic weather forecast provided by local media outlets through television or radio. The weather information provided will not include corridor specific information, and weather information will tend to be infrequent and sporadically updated. TMCs will need to focus on the weather information that is most relevant and beneficial to their operations and avoid spending time on the rest.

Level 2 – Internet provided, public access general forecasts, weather radar or satellite image or weather-specific broadcast channel. Weather information at this level of integration will provide weather data at regular intervals with information given in non-location-specific formats. Weather information at this level may be supplied to the TMC via the Internet through a private weather provider or through public forecasts. Forecasts provided will not be tailored to the needs of the TMC but rather will give a broad overview of conditions/forecasts within a given region.

Level 3 – Field observation or probes providing scheduled weather and driving condition information from entire route system. Road weather information will be reported to TMCs on scheduled intervals from field observations or instrumentations located within the right-of-way or roadway environment. The reports will provide weather information that covers all routes within the TMC jurisdiction to aid in decision making processes. These data will include:

- Road conditions
- Current weather conditions
- Past weather conditions

Level 4 – Contractor provided surface transportation weather forecasts targeted at the operational needs of the TMC agencies. This level of integration will provide corridor level forecasting tailored to the needs of a TMC in an operational setting. The tailored forecasts will be updated several times daily allowing TMCs to be aware of changing weather conditions that could affect traffic. TMCs will be able to interact with the weather provider to request weather information for specific situations. This type of communication also will permit the TMC representative to share guidance regarding how weather impacts TMC operations and how the weather provider can better support those needs. The forecasts received from the weather service provider will be much more detailed in nature than the information at the Level 2 integration. This detail will include hour by hour forecasts of:

- Road conditions
- Pavement temperature
- Deck temperature
- Precipitation type
- Precipitation rate
- Precipitation start/end times
- General atmospheric parameters

Level 5 – Direct connection between private weather information service providers and traffic management software . This level of integration will be very similar to Level 4 but takes it one step further and will provide direct communication with the weather service provider and traffic management software. This direct interface will allow for smooth transfer of weather data into traffic models. This added communication will provide TMCs a forecast of both the weather and its impacts on traffic.

6.2.2 Level of Complexity and Relative Costs

The following table describes the relative levels of complexity and cost within each level of integration when external weather information resources are used.

Table 6.4 Relative Complexity and Cost of Implementing Different Levels for the Item of Integration - External Weather Information Resources

Level of Integration	Description	Level of Complexity	Relative Cost
1	General weather information, forecasts, and interpretation provided through media as *irregular* service (radio and TV weather)	Low	Low
2	Internet provided, public access general forecasts, weather radar or satellite image or weather-specific broadcast channel	Low	Low
3	Field observers or probes providing scheduled weather / driving condition information for entire route system	Medium	Medium
4	Contractor-provided surface transportation weather forecasts targeted at the operational needs of the TMC agencies	Medium	High
5	Direct connection between private weather information service information service providers and traffic management software	High	High

6.2.3 Requirements at Various Levels of Integration

Implementing any of the above strategies has a variety of impacts and requirements in each of the five dimensions of integration. The table below identifies the steps a TMC must take to successfully achieve the specified level of integration for each dimension of integration.

Table 6.5 Requirements Across Five Integration Dimensions and Levels for the Item of Integration - External Weather Information Resources *

Operational Dimension	
Level 1	▪ Utilize radio and television reports (as available) for guidance on current and projected weather conditions.
Level 2	▪ Use radar, satellite, ASOS/AWOS, NWS zone forecasts, and media provided local forecast data to support TMC operations ▪ Conduct staff training sessions on the characteristics of these weather information resources and their use in operations
Level 3	▪ Use route specific (RWIS or MDC) data within TMC operations ▪ Conduct staff training sessions on the features of RWIS data and how to interpret their impact on traffic management
Level 4	▪ Use contractor-provided road weather information to support TMC operations ▪ Conduct staff training sessions on the characteristics of the contractor service elements and how to utilize these resources in operations
Level 5	▪ Utilize continually updated weather data in TMC operations ▪ Conduct staff training sessions on the interpretation of the weather support package and how various elements may be used to support traffic management decisions
Physical Dimension	
Level 1	▪ Acquire or designate an existing radio or television to receive the desired weather support media feed
Level 2	▪ Establish the communications link to the weather resource data ▪ Procure any necessary equipment to process or display the weather data
Level 3	▪ Establish a communications link to a source of RWIS, MDC, or related field data
Level 4	▪ Establish a communications link to a source of the post-processed weather data
Technical Dimension	
Level 2	▪ Determine the source of weather data ▪ Determine how the data will be processed internally ▪ Determine how the information will be displayed in the TMC monitors ▪ Develop or procure the necessary software to manage the data stream and permit operators to request and display the desired images or image loops
Level 3	▪ Determine the source of the RWIS, MDC, and/or related data ▪ Determine how the data will be processed internally ▪ Develop or procure the necessary software to manage the data stream and permit operators to request and display the data in the desired format
Level 4	▪ Integrate analysis products into the infrastructure developed for the previous levels of integration

Table 6.5 Requirements Across Five Integration Dimensions and Levels for the Item of Integration - External Weather Information Resources * (continued)

Procedural Dimension	
Level 2	▪ Define which ASOS/AWOS stations and zones are needed for operations ▪ Establish procedures to restore data feed and processing if a break in acquisition occurs ▪ Establish public relations material on use of weather information in TMC operations
Level 3	▪ Define which RWIS stations, MDC routes, or other resources are necessary to support operations ▪ Establish procedures to restore RWIS data feed and processing if a break in acquisition occurs ▪ Establish public relations material on use of RWIS and/or MDC information to support TMC operations
Level 4	▪ Define which products need to be accessible in TMC ▪ Establish procedures to restore access to data if a break in acquisition occurs ▪ Establish public relations material on use of all levels of service and its benefit to TMC operations
Institutional Dimension	
Level 2	▪ Determine how management may acquire access to the weather data ▪ Establish rules of practice regarding use of the weather data ▪ Map out methods for integration of the weather information into existing or planned traffic management programs
Level 3	▪ Determine how management may acquire access to the RWIS, MDC, or related data ▪ Establish rules of practice regarding use of this data ▪ Map out methods for integration of RWIS and MDC data into existing or planned traffic management programs
Level 4	▪ Determine how management may acquire access to the entire suite of weather support information ▪ Establish rules of practice regarding use of the weather support data ▪ Map out methods for integration of the various weather resources into existing or planned traffic management programs

* For all dimensions, requirements are described for the level of integration to which they first apply. If requirements are not mentioned for a higher level(s), then the last level mentioned is adequate for all the higher levels.

6.3 Item of Integration – Availability of Weather Information

This item of integration pertains to the availability of various levels of weather and road weather data and information resources within a TMC. This is not an expression of the usage of information, but the availability of information. This is usually a progression from a discrete level to a higher level and not necessarily an accumulation of all the individual components of the prior levels. Strategies range from cable TV channel providing general weather information to hiring an in-house meteorologist.

6.3.1 Strategies (or Levels of Integration)

Level 1 – Cable channel or subscription weather information vendor providing general weather information. At this level of integration weather information will be available via a

dedicated weather cable channel or a subscription with a weather vendor. The information provided by these weather providers is general in nature and will not include weather data at a corridor level. Along with the data being general in nature its availability will be irregular and sparse in spatial and temporal resolution.

Level 2 – Internet provided weather radar or satellite images on video wall. Weather radar and/or satellite imagery will provide real-time weather information to TMCs through images displayed on the video wall within the operations center. Radar and satellite will be continuously updated via the Internet which will result in real-time information. However, there is no online interpretation of the real-time information; therefore weather information may be confusing or non-beneficial for the TMC's operations.

Level 3 – Field observers or ESS network providing scheduled road or driving condition reports. Field observations or ESS networks will provide data when weather information is needed. The availability of data will be as needed or on a scheduled basis. The data can be collected from field observers on a schedule throughout the day or when weather may be affecting the route network. ESS can be scheduled to deliver data on a regular schedule or when thresholds are met by sensors and data are sent back to the TMCs.

Level 4 – Vendor provided daily surface transportation weather forecasts and observed weather conditions including Level 3. The availability of weather data provided by surface transportation weather forecast vendors will allow TMCs to better manage traffic during adverse weather. TMCs will have data when needed to make informed decisions regarding weather conditions.

Level 5 – Meteorologist, located within TMC, forecasts and interprets weather . The availability of data will be only limited to the number of weather observations and frequency of forecast updates. A meteorologist within the TMC will provide data as near real-time as possible to aid in traffic operations. The interpretation of forecast and observations by a trained meteorologist also will allow for more information to be utilized by TMCs because weather information can be quickly relayed to traffic managers in a form they can understand.

6.3.2 Level of Complexity and Relative Costs

The following table describes the relative level of complexity and cost across the levels of integration for availability of weather information.

Table 6.6 Relative Complexity and Cost of Implementing Different Levels for the Item of Integration - Availability of Weather Information

Level of Integration	Description	Level of Complexity	Relative Cost
1	Cable channel or subscription weather information vendor providing general weather information	Low	Low/Medium
2	Internet provided weather radar or satellite image on video wall	Low	Low

3	Field observers or ESS network providing scheduled road or driving condition reports	Medium	Medium
4	Vendor provided daily surface transportation weather forecasts and observed weather conditions including Level 3	Medium	High
5	Meteorologist, located within TMC, forecasting and interpreting weather	High	High

6.3.3 Requirements at Various Levels of Integration

Implementing any of the above strategies has a variety of impacts and requirements across the five dimensions of integration. Depending on the strategy or the level of integration selected from the list above, the table below identifies the requirements at various levels of integration across all the dimensions.

Table 6.7 Requirements Across Five Integration Dimensions and Levels for the Item of Integration - Availability of Weather Information *

Operational Dimension	
Level 2	▪ Weather information is viewed by TMC staff on facility monitors
Level 3	▪ Establish locations for field observers to take observations ▪ Identify locations for ESS deployment
Level 4	▪ Incorporate weather forecasts within TMCs
Physical Dimension	
Level 1	▪ Establish communication with cable channel or weather surface provider
Level 2	▪ Set-up video wall to display radar and/or satellite
Technical Dimension	
Level 5	▪ Staff meteorologists with access to Internet weather resources to support weather forecasting along with field observations, or densely packed ESS locations.
Procedural Dimension	
Level 3	▪ Provision of data in a tabulation of weather/driving conditions
Level 5	▪ Co-location of staff meteorologists with traffic managers
Institutional Dimension	
Level 5	▪ Staff meteorologists provide guidance external to main traffic management decision making ▪ Traffic management decisions require weather inputs ▪ Meteorologists and traffic managers have shared responsibilities in determination of advisory, control and treatment management decisions

* For all dimensions, requirements are described for the level of integration to which they first apply. If requirements are not mentioned for a higher level(s), then the last level mentioned is adequate for all the higher levels.

6.4 Item of Integration – Frequency of Weather Forecasts

Weather forecasts can be provided at different frequencies during a given time period. The frequency with which a forecast is provided reflects the level of information detail that is required by the TMC for decision making and higher frequencies involve a more sophisticated forecast generation and forecast utilization. This is usually a progression from a discrete level to a higher level and not necessarily an accumulation of all the individual components of the prior levels. Frequency of forecasts range from a per-request basis to hourly resolution weather forecasts.

6.4.1 Strategies (or Levels of Integration)

Level 1 – Receive information of weather forecasts on a request basis. This strategy provides for a simplistic method of gaining weather forecast information where the information will be requested as needed. This will limit the flow of information and require insight as to when weather forecast information will be needed, otherwise it is likely that weather events will transpire without the knowledge of TMC personnel regarding these changing conditions.

Level 2 – Receive weather forecast once daily. This strategy will give TMC personnel one weather forecast per day to make planning and decisions. The usefulness of this daily forecast will depend upon the length of the forecast and the detail provided in the forecast. For example, a weather forecast that provides only general conditions for broad time periods would lend little support to operations and planning. However, a weather forecast that provides specific details (e.g., air temperature, pavement conditions, and precipitation type/amounts) in hourly time intervals for greater than twenty-four hours will be meaningful for TMC operations and planning. However, the single daily forecast will not permit adjustments in forecast conditions should indicators show that the predicted conditions are not trending as expected.

Level 3 – Receive periodic (general) forecasts several times a day. This strategy will extend the features of a general condition weather forecast by permitting a refinement of the forecasted weather conditions several times a day with new forecasts. This will permit the weather forecasts to respond to new weather observations and additional weather model projections. The value of these forecasts still will be limited as the detail provided is limited in content. TMC operations would use the periodic forecasts to more frequently adjust traffic operations in response to variations in forecasted weather conditions.

Level 4 – Receive hourly resolution weather forecasts several times a day. This strategy will extend the features of a daily detailed (hourly) weather forecast by permitting a refinement of the forecasted weather conditions several times a day with new hourly resolution forecasts. This will permit the weather forecasts to respond to new weather observations and additional weather model projections. The value of these forecasts is in the detail afforded by the hourly resolution along with the updates during the day. TMC operations will use these forecasts to more frequently adjust to time critical variations in forecasted weather conditions.

Level 5 – Receive continuous updates of hourly resolution weather forecasts. In this strategy weather forecasts will be updated continuously to provide immediate response to changing weather conditions that can result in short-term and possibly mid-term weather conditions.

Typically this continuous update will be interpreted on an hourly basis, but advances in weather observing and weather modeling technologies could reduce these even more frequent updates (less than an hour). TMCs will most likely use these forecasts for rapidly changing short-term weather-related decision making.

6.4.2 Level of Complexity and Relative Costs

The following table describes the relative level of complexity and cost across all levels of integration for the frequency of weather forecasts.

Table 6.8 Relative Complexity and Cost of Implementing Different Levels for the Item of Integration - Frequency of Weather Forecasts

Level of Integration	Description	Level of Complexity	Relative Cost
1	Receive information of weather forecasts on a request basis	Low	Low
2	Receive weather forecast once daily	Low	Low
3	Receive periodic forecasts several times a day	Low	Medium
4	Receive hourly updates of weather forecasts several times a day	Low	Medium
5	Receive continuous updates of weather forecasts in real-time	Medium	High

6.4.3 Requirements at Various Levels of Integration

Implementing any of the above strategies has a variety of impacts and requirements across the five dimensions of integration. Depending on the strategy or the level of integration selected from the list above, the table below identifies the requirements at various levels of integration across for each dimension.

Table 6.9 Requirements Across Five Integration Dimensions and Levels for the Item of Integration - Frequency of Weather Forecasts *

	Operational Dimension
Level 1	▪ Define situations where weather forecast requests are made
Level 2	▪ Establish a method of distributing daily forecast information within TMC operations
Level 3	▪ Establish a method of including periodic forecast information within TMC operations that accounts for the updated information ▪ Define performance measures that assess the utilization of frequent forecast information
Level 4	▪ Establish a method of including periodic forecast information within TMC operations that accounts for the updated information
Level 5	▪ Establish a method of incorporating continuously update weather forecasts in TMC decision making

Physical Dimension	
Level 1	▪ Need internal computer hardware and software to access HTML-based weather forecast products
Level 2	▪ Need telecommunications support to manage the reception of electronically transmitted weather forecast products ▪ Need internal hardware / software system to store and manage non-HTML provided weather forecast products
Level 3	▪ Need an agency distribution system to provide notifications of forecast arrival and updates
Technical Dimension	
Level 4	▪ Define the frequency and delivery times of needed forecasts

Table 6.9 Requirements Across Five Integration Dimensions and Levels for the Item of Integration - Frequency of Weather Forecasts * (continued)

Procedural Dimension	
Level 1	▪ Develop standard operating procedures for requesting a forecast
Level 2	▪ Establish methods for reporting on the on-time arrival of weather forecasts
Level 3	▪ Establish methods for reporting on the usefulness of weather forecasts at the frequency being received
Institutional Dimension	
Level 2	▪ Need to identify a provider of weather forecasts that support the frequency and format of weather forecasts desired ▪ Establish goals and objectives for assessing the effectiveness of weather forecasts at the frequency obtained by the TMC ▪ Develop a concept of operations for incorporating into TMC operations the weather forecast information at the frequency requested
Level 4	▪ Need to identify TMC staff qualified to determine the frequency of weather forecasts needed

* For all dimensions, requirements are described for the level of integration to which they first apply. If requirements are not mentioned for a higher level(s), then the last level mentioned is adequate for all the higher levels.

6.5 Item of Integration – Frequency of Road Weather Observations

Weather observations can be acquired at varying frequencies based on the need for the information. The frequency of data acquisition generally reflects the value and level of utilization within an operational environment. Often the need for more frequent data will depend upon operational situations. More frequent data acquisition requires more sophisticated infrastructure and procedures. This is usually a progression from a discrete level to a higher level and not necessarily an accumulation of all the individual components of the prior levels. Strategies range from a per-request basis to automatic threshold notification.

6.5.1 Strategies (or Levels of Integration)

Level 1 – Receive information on road weather conditions on a request basis . In this strategy the weather conditions will be acquired by TMC personnel as necessary for planning and decision making. This requires TMC staff to evaluate weather situations that would prompt their request for weather data. This activity assumes that the staff has sufficient exposure and experience with weather situations to make appropriate requests for weather observation data.

Level 2 – Receive road weather observations once every hour. This strategy will provide TMC operators with a collection of weather observations each hour. This will require the TMC to interpret all weather observations to determine where significant changes are occurring. It will not provide weather observations collected more frequently than once per hour to be used. This strategy will not provide weather observations associated with the roadways, rather only those observations typically reported via standard weather reporting methods.

Level 3 – Receive weather/road weather observations when predefined thresholds have been exceeded. This strategy will combine the standard hourly flow of weather observations to include identification of critical operational situations, when weather observations exceed thresholds predefined by TMC personnel. This will enable TMC staff to quickly identify locations and weather situations that are most critical to their daily operations.

Level 4 – Receive weather/road weather observations every ten minutes and when predefined thresholds have been exceeded. This strategy will utilize frequently updated weather and road weather observations to provide decision support on rapidly changing conditions. The ten minute resolution data will be provided from weather and road weather observations either polled at this frequency or where these observations are triggered due to reporting criteria which identify significant changes in weather conditions. Further, using thresholds predefined by TMC personnel to identify critical operational situations, the weather and road weather observations will be provided when these thresholds are exceeded.

Level 5 – Receive weather/road weather observations continuously with data above predefined thresholds highlighted. In this strategy weather and road weather observations will flow into the TMC operations as they are observed from all possible platforms available. To provide maximum decision making support from the observations, the observations will be highlighted when they exceed a TMC defined threshold. This permits TMC personnel to immediately be notified when transportation related weather conditions become a significant factor in short-term decision making.

6.5.2 Levels of Complexity and Relative Costs

The following table describes the relative levels of complexity and cost for each level of integration associated with frequency of weather/road weather observations.

Table 6.10 Relative Complexity and Cost of Implementing Different Levels for the Item of Integration - Frequency of Road Weather Observations

Level of Integration	Description	Level of Complexity	Relative Cost
1	Receive information of weather conditions on a request basis	Low	Low
2	Receive weather observations once hourly	Low	Low
3	Level 2 plus receive weather/road weather observations when predefined thresholds have been exceeded	Low	Medium
4	Receive weather/road weather observations every ten minutes and when predefined thresholds have been exceeded	Medium	Medium
5	Receive weather/road weather observations continuously with data above predefined thresholds highlighted	Medium	High

6.5.3 Requirements at Various Levels of Integration

Implementing any of the above strategies has a variety of impacts and requirements within each of the five dimensions of integration. The table below identifies the steps a TMC must complete to successfully achieve the specified level of integration within the associated dimension of integration.

Table 6.11 Requirements Across Five Integration Dimensions and Levels for the Item of Integration - Frequency of Road Weather Observations *

Operational Dimension	
Level 1	▪ Define situations when weather conditions information requests are made and by whom
Level 2	▪ Establish a method of distributing weather and road weather data within TMC operations at the frequency of arrival ▪ Define the frequency at which certain data elements are needed
Level 3	▪ Establish a method of including weather and road weather observations within TMC operations that accounts for the updated information ▪ Define performance measures that assess the utilization of weather and road weather observations relative to the frequency of acquisition
Level 4	▪ Establish a method of adjusting the thresholds for weather *highlighting???* and acquisition that reflects the operational needs
Level 5	▪ Establish a method of incorporating continuously received weather and road weather observations in TMC decision making
Physical Dimension	
Level 1	▪ Need internal computer hardware and software to access HTML-based displayed weather observations
Level 2	▪ Need telecommunications support to manage the reception of electronically transmitted weather and road weather observational data ▪ Need internal hardware / software system to store and manage non-HTML provided weather and road weather observations
Level 3	▪ Need an agency distribution system to provide notifications of weather and road weather observations that exceed threshold values
Level 4	▪ Need an archival process to retain observations for *post-storm* debriefing and potential training purposes
Technical Dimension	
Level 3	▪ Define the frequency of *weather and road weather* observations needed and the appropriate delivery times
Level 4	▪ Need a software capability to process *weather and road weather* observations coming from differing sources and of differing types (e.g., ESS vs. ASOS observations)
Level 5	▪ Need a software capability to process weather and road weather observations coming from differing sources and of differing types (e.g., ESS vs. ASOS observations)
Procedural Dimension	
Level +2	▪ Establish checklist for determining when to request data ▪ Establish methods for reporting on the on-time arrival of weather and road weather observations ▪ Establish performance measures to evaluate the timeliness of weather and road weather observations

Level 3	▪ Establish methods for reporting on the usefulness of weather forecasts at the frequency being received
Level 4	▪ Establish a method to initiate observations acquisition, the modification of observations acquisition, and the setting of thresholds within the acquisition process
Level 5	▪ Create a procedure to ensure that only quality controlled data are used by TMC for decision making

Table 6.11 Requirements Across Five Integration Dimensions and Levels for the Item of Integration - Frequency of Road Weather Observations * (continued)

Institutional Dimension	
Level 2	▪ Define the requirements associated with *weather and road weather* observations acquisition and the appropriate procurement process
Level 3	▪ Define the administrative process to manage the flow of *weather and road weather* observations within the TMC infrastructure ▪ Define the process to address quality issues associated with observation data
Level 5	▪ Establish organization process that institutionalizes the effective and efficient use of weather and road weather observations in TMC operations

* For all dimensions, requirements are described for the level of integration to which they first apply. If requirements are not mentioned for a higher level(s), then the last level mentioned is adequate for all the higher levels.

6.6 Item of Integration – Weather Information Coordination

Weather information coordination involves the exchange of information to support decision-making and operations within a TMC. Increasing levels of integration relate to an increase in the personnel committed to lead the utilization of weather data/information in the TMC. This is usually a progression from a discrete level to a higher level and not necessarily an accumulation of all the individual components of the prior levels. Strategies range from intra-TMC committees to co-location of EOCs.

6.6.1 Strategies (or Levels of Integration)

Level 1 – Intra-TMC committee tasked with weather information coordination. This strategy will provide a rudimentary process to incorporate weather information into the TMC operation environment. Formation of a local committee will provide a central structure to address weather information-related TMC activities and foster discussions to identify weather-related needs and methods to address those needs. This effort will most likely exclude any external or internal meteorologist input.

Level 2 – Identified TMC or maintenance staff member tasked with coordinating weather information at TMC. This strategy will build an intra-TMC weather information coordination committee with a staff member assigned to coordinate weather information activities within the TMC, or assign a single staff member to explore the same issues as the intra-TMC committee with an additional responsibility to perform ongoing efforts to better identify and address weather needs. This will be an individual with a partial or full-time assignment to coordinate weather information.

Level 3 – Dedicated weather operations supervisor. In this strategy the TMC will commit personnel to support weather operations. To ensure these weather operations are coordinated and best utilized in the TMC, a supervisory staff position will be created with oversight of the TMC weather operations. The benefit will be to address daily weather needs and concerns and provide

a person who can attend to weather operations planning and implementation efforts. The supervisor will not be a meteorologist but an individual who has experience and/or exposure to weather–related activities in the TMC.

Level 4 – Meteorology staff forecasting and interpreting weather information in the TMC. This strategy will provide for the presence of trained meteorologists within the TMC to work in cooperation with transportation personnel. This will enable the TMC to utilize the meteorologists to interpret changing weather conditions on behalf of the transportation staff and assist with coordination activities including providing support for forecasting using all available data.

Level 5 – Co-location of the Emergency Operations Center/Office of Emergency Management.- In this strategy the effort of TMC weather and road weather utilization, including the presence of meteorology staff, will be incorporated with emergency management and emergency response activities. This cross-agency utilization will permit the TMC to use weather and road weather information to maximize the traffic management activities during emergencies.

6.6.2 Levels of Complexity and Relative Costs

The following table describes the relative levels of complexity and cost for each level of integration associated with weather information coordination.

Table 6.12 Relative Complexity and Cost of Implementing Different Levels for the Item of Integration - Weather Information Coordination

Level of Integration	Description	Level of Complexity	Relative Cost
1	Intra-TMC committee tasked with weather information coordination	Low	Low
2	Identified TMC or maintenance staff member tasked with coordinating weather information at TMC	Low	Low
3	Dedicated weather operations supervisor	Medium	Medium
4	Meteorology staff located within the TMC forecasting and interpreting weather information	High	High
5	Co-location of the EOC/OEM	High	High

6.6.3 Requirements at Various Levels of Integration

Implementing any of the above strategies has a variety of impacts and requirements within each of the five dimensions of integration. The table below identifies the steps a TMC must complete to successfully achieve the specified level of integration within the associated dimension of integration.

Table 6.13 Requirements Across Five Integration Dimensions and Levels for the Item of Integration - Weather Information Coordination *

Operational Dimension	
Level 1	▪ Establish lines of communications between the TMC and identified meteorologists ▪ Establish an email list of points-of-contact in the weather community ▪ Periodic staff meetings to discuss weather information needs
Level 2	▪ Exchange weather issues of interest using a local TMC managed list-serve that includes both TMC staff and in-house and external weather staff ▪ Create a list of contacts with associated regions for weather expertise that are important to the TMC activities ▪ Provide routine orientation briefings of TMC staff on weather information availability and seek staff input on needs ▪ Local forums are held between TMC staff and local meteorological community ▪ Acquire staff training on weather information
Level 3	▪ Conduct discussion groups that address operational regions where weather information coordination is most needed in TMC operations ▪ Weather supervisor leads discussion with TMC staff on recent weather events where weather could be used more efficiently ▪ Weather supervisor provides training activities with TMC staff on weather information available in-house and externally ▪ TMC staff participate in regional and national weather conferences associated with surface transportation weather
Level 4	▪ In-house meteorology staff conduct routine briefings to TMC staff on pending weather concerns ▪ In-house meteorology staff provide case studies of weather events that have impacted TMC operations with TMC staff providing discussion of how they could better respond to these events in the future ▪ Coordinate efforts among TMC, maintenance operations and weather providers (in-house and external)
Level 5	▪ Establish operational coordination between TMC, EOC and weather community on significant weather-related events
Physical Dimension	
Level 1	▪ Construct a database of contacts within the TMC and weather community who will be involved in interaction efforts
Level 2	▪ Provide communications interface that links TMC staff member tasked with coordination of weather information with TMC supervisory personnel ▪ Provide communications support for in-house meteorology staff that provides effective sharing of information between traffic management activities and meteorological analysis and forecast activities
Level 3	▪ Provide information message and notification system that facilitates rapid-responses between traffic management staff and meteorologists (in-house and external)
Level 5	▪ Provide networked communications interfaces that links weather information providers (in-house and/or external) with TMC, maintenance and/or EOC personnel
Technical Dimension	
Level 1	▪ Email communication between TMC staff and weather staff and advisors
Level 2	▪ Active list-serve for exchange of coordination information
Procedural Dimension	
Level 2	▪ Develop a checklist of routine weather awareness activities to conduct with staff

Level 3	▪ Define chain of command for coordination by weather staff or external weather advisors with TMC staff
Level 4	▪ Establish methods to advise TMC management of weather information coordination issues
Level 5	▪ Develop methods to address lack of personnel utilization of available weather information

Table 6.13 Requirements Across Five Integration Dimensions and Levels for the Item of Integration - Weather Information Coordination * (continued)

Institutional Dimension	
Level 1	▪ Seek advice of weather consultant
Level 3	▪ Establish criteria required for staff member qualified to lead weather information coordination efforts
Level 4	▪ Include coordination and travel support with the surface transportation weather community as a management commitment to weather integration efforts

* For all dimensions, requirements are described for the level of integration to which they first apply. If requirements are not mentioned for a higher level(s), then the last level mentioned is adequate for all the higher levels.

6.7 Item of Integration – Extent of Coverage

Coverage of weather information is critical to address site-specific weather-related issues. The increase in focused coverage area expresses an increase in the level of integration as more detailed and greater quantities of data and information are required. This is usually a progression from a discrete level to a higher level and not necessarily an accumulation of all the individual components of the prior levels.

6.7.1 Strategies (or Levels of Integration)

Level 1 – Expand the coverage of weather information to include a sparse set of isolated locations. This strategy will involve the collection of weather information from a set of isolated locations known to be impacted by severe weather. Examples of potential locations include low water crossings, bridges, mountain passes, etc. Generally weather information will be generated from agency-owned weather monitoring stations. These stations may be attached directly to specific traffic advisory, control, and treatment devices as stand-alone systems. Traffic advisory, control, and treatment responses will be designed to address weather-related impacts at those specific locations only.

Level 2 – Expand the extent of coverage to a network of sensors in scattered locations. Instead of obtaining weather information from one or two isolated locations, weather information will be obtained from a network of strategically-located sites (5 to 10 locations) scattered throughout a region or urban area. The purpose of this network of sites will be to obtain a general overview of the weather conditions. The TMC operator will be able to use the information from the network to monitor the path and extent of changing weather conditions as well as to make strategic decisions for distributing resources and personnel. Information from these locations could also be used to provide advisory information via a website. Devices used to provide information will primarily be owned by the operating agency; however, agencies might consider integrating information from privately-owned devices, or devices owned by other operating agencies to complete the network or to fill in gaps where information is missing.

Level 3 – Expand the extent of coverage to a network of sensors that provide corridor-level weather information. In this strategy, an agency will expand the coverage of weather information devices to provide information about weather conditions from multiple locations in a specific corridor. The information will be obtained from specific locations in the corridor known to experience traffic problem caused by weather conditions. The corridor may consist of only a single facility or may be composed of multiple facilities serving similar trips (for example, a freeway and parallel arterials). The information will allow a TMC operator to make tactical decisions about what type of traffic advisory, control, and treatment strategies to implement in the corridor. Examples of strategies that could be implemented with this level of deployment include coordinated signal timing plans to promote traffic movement on an emergency or evacuation route and deploying diversion routing around a flooded section of roadway. Weather information will need to be tightly coupled with traffic information from the corridor. This level of integration will be needed to support automated traffic management responses.

Level 4 – Expand the extent of coverage to a network of sensors to provide weather information from multiple corridors or areas within a region. This strategy will include obtaining weather-related information from multiple locations within multiple corridors in order to implement a coordinated response from multiple agencies. Most likely the systems and devices used to obtain weather information will not be owned by a single agency, but will be owned by multiple agencies and jurisdictions. TMC software will need to be able to support the integration of weather information from multiple agencies. Weather-related information may also be obtained from private weather information service providers. Weather information will need to be highly integrated with traffic data. Emergency evacuation routes and diversion routes are good examples of where this level of integration might be appropriate.

Level 5 – Expand the extent of coverage to a network of sensors to provide weather information for the entire state. This level of integration will be needed to support information dissemination activities on a statewide basis and will be directed towards long-distance and intercity travel with weather information. The primary application of this level of deployment will include statewide 511 calling centers and internet traveler information sites. TMCs will likely use information from locations outside their jurisdiction to inform travelers of developing weather situations, promote the use of alternative routes, and encourage travelers to delay or postpone trips leaving a jurisdiction. Private weather information providers will be likely mechanisms to augment agency-owned weather monitoring sites.

6.7.2 Levels of Complexity and Relative Costs

The following table describes the relative levels of complexity and cost across the levels of integration associated with extent of weather information coverage.

Table 6.14 Relative Complexity and Cost of Implementing Different Levels for the Item of Integration - Extent of Coverage

Level of Integration	Description	Level of Complexity	Relative Cost
1	Expand the extent of coverage of weather information to include a sparse set of isolated locations	Low	Low
2	Expand the extent of coverage to a network of sensors in scattered locations	Medium	Medium
3	Expand the extent of coverage to a network of sensors to provide corridor-level weather information	Medium	Medium
4	Expand the extent of coverage to a network of sensors to provide weather information from multiple corridors or areas within region	High	High
5	Expand the extent of coverage to a network of sensors to provide weather information for the entire State	High	High

6.7.3 Requirements at Various Levels of Integration

Implementing any of the above strategies has a variety of impacts and requirements across the five dimensions of integration. Depending on the strategy or the level of integration selected from the list above, the table below identifies the requirements at various Levels of Integration across all the dimensions.

Table 6.15 Requirements Across Five Integration Dimensions and Levels for the Item of Integration - Extent of Coverage *

Operational Dimension	
Level 1	▪ Establish "sensor triggers" to notify TMCs when specific sensors or stations have reported activity indicating a weather condition ▪ If triggered sensors at specific locations are not tied to an alert mechanism, TMC should issue a point specific alert
Level 2	▪ TMC to use weather information from sensor network to issue general advisory statements, using standard information dissemination capabilities such as DMS and websites
Level 3	▪ TMC to use weather information from sensor network to issue corridor specific weather advisory statements ▪ TMC system software should make automated suggestions for advisory messages ▪ TMC system software should make suggestions on corridor-specific decisions which can alert and/or reduce impact of weather conditions
Level 4	▪ TMC system software must make predictive readings on weather event movements in conjunction with traffic data forecast to issue predictive weather advisories on regional corridors

Level 5	▪ TMC system software must be integrated into 511 calling system as well as statewide traveler information sites

Table 6.15 Requirements Across Five Integration Dimensions and Levels for the Item of Integration - Extent of Coverage * (continued)

Physical Dimension	
Level 1	▪ At a minimum, need an accessible communications link to each information source
Level 2	▪ Need to establish a standardized reporting or polling scheme for system sensors to transfer information to TMC on a routine basis ▪ Need to establish a "back room" infrastructure to support the polling / reporting process to system sensors ▪ Obtain access to external information source(s) (i.e. radio station, Internet, weather service provider) to expand system sources of information ▪ Need to develop infrastructure capable of sharing sensor system alerts to appropriate agencies
Level 3	▪ Need agency infrastructure capable of sending automated alerts to motorists ▪ Need agency infrastructure capable of operating with other agency infrastructure to affect control decisions (i.e. change of signal timing plans)
Level 4	▪ Expand sensor system
Level 5	▪ Need infrastructure developed to interface with statewide data center ▪ Need infrastructure developed to interface with statewide 511 systems
Technical Dimension	
Level 1	▪ Determine the data reporting parameters and message components of each sensor type to insure information is captured accurately
Level 2	▪ Need to establish an analysis routine of system data which can monitor the path and extent of changing weather conditions based on sensor reports
Level 3	▪ Need to enhance analysis routines of system data to a more discrete corridor level to monitor and project changing weather conditions that would impact a specific travel corridor ▪ Need to integrate sensor system data with traffic information to analyze developing condition from the standpoint of affected traffic
Level 4	▪ Need to incorporate data archiving routines with sensor and traffic data analysis to facilitate current predictions based on historical events ▪ Need real-time analysis and predictive capabilities of sensor and traffic data to facilitate planning in emergency operations, such as evacuations
Level 5	▪ Need to develop automation capabilities for interfacing to 511 systems. ▪ Need to develop automated information update capabilities and alert feeds to statewide traveler information sites
Procedural Dimension	
Level 1	▪ Develop standard operating procedures for monitoring of sensor network by TMC operators ▪ Establish appropriate procedures for monitoring the health of sensor and communication systems
Level 2	▪ Develop standard operating procedures for internal and external notification of sensor alerts ▪ Develop standard procedures for keeping information dissemination methods updated (media, web, etc) ▪ Establish mechanisms for reporting on the effectiveness and timeliness of weather-related TMC alerts
Level 3	▪ Establish levels for automatic implementation of control system based on sensor and traffic data

Level 4	▪ Define TMC information exchange procedures with other agencies to implement automated plans
Level 5	▪ Develop information exchange procedures to feed alerts and updates to 511 systems ▪ Develop information exchange procedures to feed alerts and updates to statewide traveler information systems

Table 6.15 Requirements Across Five Integration Dimensions and Levels for the Item of Integration - Extent of Coverage * (continued)

Institutional Dimension	
Level 1	▪ Obtain permission from appropriate agencies to place sensors at strategic locations ▪ Identify funding sources for procuring systems, maintenance and operations, and regular and recurring training for field sensors systems
Level 2	▪ Develop data sharing agreement with appropriate agencies to allow access to sensors at additional strategic locations ▪ Establish MOU / Inter-agency agreement to allow for joint monitoring of field devices by multiple agencies ▪ Define the level of commitment and partnership between agencies for participating in systems for weather alert notifications
Level 3	▪ Liaison with other operating agencies and relevant entities to establish an appropriate basis for sharing alert information and implementing strategic responses
Level 4	▪ Establish MOU / Inter-agency agreement to allow for joint control of field infrastructure to achieve coordinated control of traffic during significant events
Level 5	▪ Establish MOU / Inter-agency agreement to for information flow to 511 systems

* For all dimensions, requirements are described for the level of integration to which they first apply. If requirements are not mentioned for a higher level(s), then the last level mentioned is adequate for all the higher levels.

6.8 Item of Integration – Interaction with Meteorologists

Training on weather data interpretation and management is not a common activity for TMC personnel. Interaction with meteorologists by TMC personnel provides opportunities to learn more about how to incorporate weather information in TMC operations. The level of integration increases with the frequency of exposure to meteorologists. This is usually a progression from a discrete level to a higher level and not necessarily an accumulation of all the individual components of the prior levels.

6.8.1 Strategies (or Levels of Integration)

Level 1 – Focus group or informal gatherings of local professionals from the transportation management and weather communities. This strategy will provide an opportunity for the transportation management and weather professionals to exchange views. The advantage of this effort is that it promotes familiarization of mutual opportunities in surface transportation weather and fosters a sense of shared values.

Level 2 – Develop check list of routine weather awareness activities. In this strategy the focus group or informal gatherings of local professionals in the transportation management and weather communities will pursue activities to heighten the awareness of mutual interests, needs, and challenges in surface transportation weather. These activities will result in the development of a structured check list of routine weather awareness efforts that will be addressed as a shared activity.

Level 3 – Periodic staff meeting that includes a meteorologist to discuss weather information needs and responses. This strategy will provide the opportunity for the TMC without a meteorology staff to discuss weather information needs and responses. This discussion will permit meteorologists to provide an orientation on existing solutions that could be considered by the TMC staff to improve the utilization of weather information in making decisions. The participation of a meteorologist will be on an infrequent basis but potentially with increasing frequency as the TMC improves its weather integration efforts.

Level 4 – With a full-time meteorologist present, conduct post-event debriefing / regular assessment to fine-tune responses. This strategy will incorporate a meteorologist in the assessment and/or evaluation of TMC responses to weather-related events. The advantage to the TMC will be the interpretation of the nature and evolution of problem during the weather event. This will permit TMC staff to understand the predictability and frequency of the event and an evaluation of methods to improve the decision making process through improved and/or more efficient incorporation of weather data and information.

Level 5 – Daily personal briefings and integrated interpretations by one or more full-time meteorology staff within the TMC. This strategy will provide the greatest level of interaction between meteorologists and TMC staff in the daily operations.. The daily briefings and integrated weather and traffic interpretation will provide optimal support for weather-responsive decision making.

6.8.2 Level of Complexity and Relative Costs

The following table describes the relative levels of complexity and cost for each level of integration associated with the interactions with meteorologists.

Table 6.16 Relative Complexity and Cost of Implementing Different Levels for the Item of Integration - Interaction with Meteorologists

Level of Integration	Description	Level of Complexity	Relative Cost
1	Focus group or informal gatherings of local professionals from the transportation management and weather communities	Low	Low
2	Develop check list of routine weather awareness activities	Low	Low
3	Periodic staff meetings that include a meteorologist to discuss weather information needs and responses	Low	Low
4	With a meteorologist present conduct post-event debriefing / regular assessment to fine-tune responses	Medium	Low/Medium
5	Daily personal briefings and integrated interpretations by meteorology staff within the TMC	High	High

6.8.3 Requirements at Various Levels of Integration

Implementing any of the above strategies has a variety of impacts and requirements within each of the five dimensions of integration. The table below identifies the steps a TMC must complete to successfully achieve the specified level of integration within the associated dimension of integration.

Table 6.17 Requirements Across Five Integration Dimensions and Levels for the Item of Integration - Interaction with Meteorologists *

Operational Dimension	
Level 1	▪ Attend local joint meetings between the weather and transportation communities
Level 2	▪ Attend national/regional joint meetings between the weather and transportation communities ▪ Update checklist of routine weather awareness activities ▪ Host local joint meetings between the weather and transportation communities
Level 3	▪ Create a checklist of routine weather awareness activities ▪ Conduct periodic, scheduled meetings with staff to discuss weather information needs and responses (with meteorologist participation)
Level 4	▪ Host regional joint meetings between the weather and transportation communities ▪ Hold weather event related debriefings between TMC staff and the weather community and/or in-house meteorology staff
Level 5	▪ Host national joint meetings between the weather and transportation communities ▪ Conduct daily briefings that include a discussion of weather conditions and events ▪ Conduct a performance assessment that identifies the effectiveness of the interaction with the meteorological community
Physical Dimension	
Level 2	▪ Provide communications interface that includes a remote link between consulting meteorologist and TMC personnel ▪ Provide communications support for in-house weather discussion that provides effective exchanges of information between traffic management activities and meteorological analysis and forecast activities
Level 3	▪ Provide information message and notification system that facilitates rapid-responses between traffic management staff and meteorologists (in-house and external)
Technical Dimension	
Level 1	▪ Email communication between TMC staff and weather staff and advisors
Level 2	▪ Active list serve for exchange of coordination information
Procedural Dimension	
Level 1	▪ Establish methods to identify reliable and relevant weather community stakeholders of interest to the TMC
Level 2	▪ Establish guidelines for communications between the weather community and TMC staff ▪ Develop a decision making process that identifies TMC staff who are required to interact with the weather/road weather community
Level 3	▪ Develop protocols for addressing weather related traffic management issues with the weather community ▪ Develop a procedure for identifying weather-related events that require a post-event debriefing

Level 4	▪ Develop a review protocol to respond to performance issues related to more effective interaction with meteorologists

Table 6.17 Requirements Across Five Integration Dimensions and Levels for the Item of Integration - Interaction with Meteorologists * (continued)

Institutional Dimension	
Level 3	▪ TMC administrative support for staff (and administrators) to engage in dialogue with the weather and transportation communities
Level 5	▪ Establish professional requirements for TMC staff to gain training on surface transportation weather management

* For all dimensions, requirements are described for the level of integration to which they first apply. If requirements are not mentioned for a higher level(s), then the last level mentioned is adequate for all the higher levels.

6.9 Item of Integration - Alert Notification

Alert notifications provide an information exchange process to heighten awareness of weather-related operational issues. The level of integration increases as the information exchange method becomes more aggressive/engaging to the TMC operations. This is usually a progression from a discrete level to a higher level and not necessarily an accumulation of all the individual components of the prior levels. Strategies range from passive monitoring of weather outlets to automatic notification through center to center communications.

6.9.1 Strategies (or Levels of Integration)

Level 1 – Monitor media outlet, Internet pages, or data stream for critical events. In this strategy, TMC operators will simply monitor media outlets, Internet pages and other weather-related data streams to observe when weather conditions at critical locations might justify a response. Under this strategy, weather information will be used solely by the TMC. The TMC might use this information to place messages on dynamic message signs, or highway advisory radio, but there will be no communications to external response providers (such as police or maintenance crews).

Level 2 – Telephone call list. This strategy will involve not only monitoring developing weather events, but also notifying appropriate response personnel when weather events will potentially impact traffic operations. Notification could occur prior to the event occurring and as the event develops. Notification will occur manually via a telephone call to the appropriate response personnel. TMC operators will need to develop a call list of emergency and maintenance personnel that should be contacted in the event of an impending or developing weather event. The list should include the names and contact information for key response and/or operations personnel within a geographic region. The list should include geographic agency responsibility, radio frequencies or cellular telephone numbers, talk groups, primary and backup phone numbers, FAX numbers, designated alternative contact and/or supervisor. Agencies may also want to include 24-hour contact information for the following types of special equipment providers and emergency responders:

- Highway construction, maintenance, and environmental contractors,

- Traffic control contractors, and barrier wall suppliers,
- Trucking services, dump trucks, flatbeds, and roll-off dumpsters,
- Heavy equipment rental, end loaders, cranes, street sweepers,
- Radio and television media outlets, and
- Public information officers for other response agencies.

Level 3 – Manual email/paging system. This strategy will replace the telephone call system with a manual email or paging system. Operators in the TMC will send email alerts of developing or impending weather events to key responders. The advantage of this type of system over a telephone call list is that multiple individuals can be notified simultaneously, thereby decreasing the time it takes to notify key individuals. Individuals needing more information can then contact the TMC to obtain more detailed information about the impacts and threats caused by the weather event.

Level 4 – Automated TMC road weather system-generated notifications (e.g., Email or page from Road Weather Information System or Flood Early Warning System)**.** With this strategy, weather related alerts will be sent to key response personnel on the call list automatically by road weather monitoring equipment. The systems will send the emails or pages directly to response personnel, replacing the need for the TMC operator to formulate a specific message. However, there still might be situations in which TMC personnel will want to include communications with field staff in addition to automated communications. The TMC will need to develop the structure and format of the messages. Depending upon the type of road weather monitoring system installed within particular locations, responders can receive detailed weather information, including the following:

- Air temperature;
- Dew point or relative humidity;
- Precipitation occurrence, type and intensity;
- Precipitation accumulation and water level;
- Wind speed and direction;
- Visibility distance; and
- Pavement temperature, freezing point, condition, and chemical concentration.

Level 5 – Automatic notification through Center-to-Center communications. With this strategy, notification of weather-related information that might impact traffic operations will occur automatically through a Center-to-Center communications network. A road weather monitoring system will provide a continuous steam of weather-related information into a communications network linking the TMC with other weather-related emergency responders. Response agencies will "subscribe" to the type and location of weather information they deem important to their responses. Software at these centers will automatically generate alarms when a threshold defined by the different response agencies is reached. This will allow each individual agency to optimize response "triggers."

6.9.2 Level of Complexity and Relative Costs

The following table describes the relative levels of complexity and costs across various levels of integration for alert notification.

Table 6.18 Relative Complexity and Cost of Implementing Different Levels for the Item of Integration - Alert Notification

Level of Integration	Description	Level of Complexity	Relative Cost
1	Monitor media outlet, internet page, or data stream for critical events	Low	Low
2	Telephone call list	Low	Low
3	Manual email/paging system	Medium	Medium
4	Automated TMC road weather system-generated notifications (e.g., Email or page from Road Weather Information System or Flood Early Warning System)	High	High
5	Automatic notification through Center-to-Center communications	High	High

6.9.3 Requirements at Various Levels of Integration

Implementing any of the above strategies has a variety of impacts and requirements across the five dimensions of integration. Depending on the strategy and level of integration selected from the list above, the table below identifies the requirements across all dimensions of integration.

Table 6.19 Requirements Across Five Integration Dimensions and Levels for the Item of Integration - Alert Notification *

Operational Dimension	
Level 2	▪ Establish "weather triggers" to notify TMC's when weather events have developed that require TMC staff action ▪ Define performance measures to gauge effectiveness and timeliness of weather alerts in conjunction with agency goals and objectives ▪ Establish a hierarchy of weather alert information dissemination
Level 3	▪ Develop "library" of alert messages and operator actions
Level 4	▪ Automate weather alerts from RWIS or similar systems to TMC operators ▪ Define level of operator interaction (i.e. approval required) for automated messaging of weather alerts ▪ Identify field devices and locations for data collection to support weather alert systems ▪ Establish integrity of field data reporting systems and integration into TMC system software

Table 6.19 Requirements Across Five Integration Dimensions and Levels for the Item of Integration - Alert Notification * (continued)

Physical Dimension	
Level 1	▪ Need access to external information source(s) (i.e. radio station, Internet, weather service provider)
Level 2	▪ Need telecommunication service internal to TMC to call telephone list
Level 3	▪ Need an agency-level email system capable of generating mass email to stored distribution list ▪ Need an agency-level paging system capable of autodialing a stored distribution list ▪ Identify interconnections for exchanging weather information between TMC and other agencies
Level 4	▪ Establish infrastructure to support high-end systems, such as automatic notifications or Center-To-Center ▪ Identify resource requirements for weather-related components ▪ Establish communication pathway between weather system components and TMC ▪ Determine hardware and software components necessary to accomplish integration of weather alerts and TMC software
Technical Dimension	
Level 3	▪ Define a pre-established message structure and content for distributing weather related alerts to email/paging distribution lists
Level 4	▪ Define data flows for weather information between field devices, software systems, and TMC personnel ▪ Establish display and update requirements for visual display of weather information or alerts within TMC operator station ▪ Establish communication protocols and message set standards for road weather information systems or similar devices ▪ Identify data elements and storage mechanisms for retaining information to generate performance measures ▪ Define interface requirements between systems sharing weather information ▪ Establish a Center-To-Center infrastructure with identified agencies for sharing information, including weather alerts
Procedural Dimension	
Level 1	▪ Develop standard operating procedures for monitoring of weather information by TMC operators
Level 2	▪ Develop standard operating procedures for notification regarding weather alerts ▪ Develop procedures for keeping notification lists current ▪ Establish appropriate procedures for maintaining weather-related components ▪ Establish mechanisms for reporting on the effectiveness and timeliness of weather-related TMC alerts
Level 3	▪ Define TMC operator responsibilities within the weather alert notification system
Level 5	▪ Establish levels for automatic notification of weather alerts using Center-To-Center infrastructure

Table 6.19 Requirements Across Five Integration Dimensions and Levels for the Item of Integration - Alert Notification * (continued)

Institutional Dimension	
Level 2	▪ Need defined list of agencies to contact when notifying regarding specific types of weather alerts ▪ Establish goals and objectives for assessing the effectiveness and timeliness of weather-related TMC alerts ▪ Identify agency champions for participation in weather alert notification systems ▪ Develop concept of operations formalizing desired weather-integration responses ▪ Define the level of commitment and partnership between agencies for participating in systems for weather alert notifications ▪ Identify funding sources for procuring systems, maintenance and operations, and regular and recurring training for weather notification systems
Level 4	▪ Establish MOU / Inter-agency agreement to allow for joint monitoring of field devices by multiple agencies
Level 5	▪ Establish MOU / Inter-agency agreement to construct and participate in a Center-To-Center infrastructure

* For all dimensions, requirements are described for the level of integration to which they first apply. If requirements are not mentioned for a higher level(s), then the last level mentioned is adequate for all the higher levels.

6.10 Item of Integration - Decision Support

Decision support involves the use of weather information to make effective transportation management/operations decisions. The level of integration increases as the use of more advanced information, procedures and technology is incorporated in the decision making process. This is usually a progression from a discrete level to a higher level and not necessarily an accumulation of all the individual components of the prior levels.

6.10.1 Strategies (or Levels of Integration)

Level 1 – Ad-hoc implementation of weather management strategies. Under this strategy, operators in the TMC will manage the impacts of weather on traffic operations on an ad-hoc basis. Using detection and surveillance technologies, operators will observe and monitor the effects and impacts that particular weather events have on traffic operations and adjust the advisory, control, and treatment responses based on these observations. TMC operations may have general knowledge about what types of actions to implement (based upon previous experience) but will not necessarily have any formalized, pre-planned approach to managing traffic during bad weather.

Level 2 – Use quick reference flip cards on operator's workstation to implement predefined response. Under this strategy, TMC response personnel will meet with other stakeholders and responders and develop a series of pre-defined advisory, control, and treatment responses to be performed during specific weather events. These predefined responses will be incorporated into

the standard operating procedures of the TMC, and operators will have ready access to these responses, either through the use of flip cards or other documentation. Weather event thresholds will be defined that trigger specific types of responses by the TMC operators.

Level 3 – Response scenarios are supplied through software that identifies potential solutions with projected outcomes based on weather/traffic models. Under this strategy, a decision support tool will be developed to allow the operator to generate potential advisory, control, and treatment responses based upon information about developing weather conditions. This decision support tool will incorporate criteria and triggers for different types of agency responses. The operator will be required to enter specific information about a developing weather event through an interface, and the system will then identify potential solutions and strategies based on a predefined set of "rules" or desired responses. Under this strategy, the operator will have the primary responsibility of both entering the appropriate weather information and implementing the appropriate advisory, control, and treatment responses.

Level 4 – Automated condition recognition and advisory or control strategies presented to operator for acceptance into ATMS. This strategy will involve developing a decision support tool similar to that defined in Level 3; however, under this strategy, weather information will be fed directly into the tool as opposed to the TMC operator entering the information. Devices in the field and other sources of weather information will communicate directly with the decision support tool, feeding it with real-time information about weather conditions. The decision support tool will continuously monitor the weather information feed, "recognize" when weather conditions have reached pre-defined thresholds, and then identify for the operator appropriate advisory, control and treatment actions. The operator will then use existing tools and systems in the TMC to implement (or refine) the responses. The operator will remain a vital element of the response process. The operator will use the TMC's detection and surveillance technologies to fine-tune the response as traffic and weather conditions change.

Level 5 – Automated condition recognition and advisory or control strategy implemented without operator intervention. This strategy will involve developing a fully automated decision support system that will automatically retrieve information from weather information sources, identify appropriate advisory, control and treatment responses based on the available weather information, and then implement a response without requiring the TMC operator to interact with the system. The TMC operator may be notified that a response has taken place and the operator will have the ability to fine-tune the response, but the initial implementation of the response will occur in an automated fashion. These systems can be developed to address problems at local isolated locations and to address situations throughout an entire metropolitan region. These systems will require high levels of communication between different sources of weather information. These systems will also require tight coupling between the decision support tool and the TMC software, and may in fact be directly integrated with the TMC software.

6.10.2 Level of Complexity and Relative Costs

The following table describes the relative levels of complexity and costs across various levels of integration for decision support.

Table 6.20 Relative Complexity and Cost of Implementing Different Levels for the Item of Integration - Decision Support

Level of Integration	Description	Level of Complexity	Relative Cost
1	Ad-hoc implementation of weather management strategies	Low	Low
2	Use quick reference flip cards on operator's workstation to implement predefined response	Medium	Medium
3	Response scenarios are supplied through software that identifies potential solutions with projected outcomes based on weather/traffic models	Medium	Medium
4	Automated condition recognition and advisory or control strategies presented to operator for acceptance into ATMS	High	High
5	Automated condition recognition and advisory or control strategy implemented without operator intervention	High	High

6.10.3 Requirements at Various Levels of Integration

Implementing any of the above strategies has a variety of impacts and requirements across the five dimensions of integration. Depending on the strategy or the level of integration selected from the list above, the table below identifies the requirements at various levels of integration across all the dimensions.

Table 6.21 Requirements Across Five Integration Dimensions and Levels for the Item of Integration - Decision Support *

Operational Dimension	
Level 1	▪ Establish "Weather triggers" as a baseline for TMC operators to implement appropriate ad-hoc responses
Level 2	▪ Train TMC operators in implementation of pre-defined sequences, focusing on data sources, trigger points, and follow-up actions
Level 4	▪ Develop a set of rules for categorizing weather information and identifying specific triggers for the decision support system
Level 5	▪ Develop a set of rules for generating advisory, control, and treatment responses automatically from the decision support system
Physical Dimension	
Level 1	▪ Need access to readily available weather information source(s) (i.e. cameras, radio station, Internet, weather service provider, filed sensors, etc
Level 3	▪ Operator needs to view weather information sources and have available interface for data entry into decision support system

Level 4	▪ Need access to automated data inputs into decision support system from weather information sources
Level 5	▪ Integrate decision support tool with TMC software to allow generated responses to be implemented automatically

Table 6.21 Requirements Across Five Integration Dimensions and Levels for the Item of Integration - Decision Support * (continued)

Technical Dimension	
Level 3	▪ Develop system architecture to allow for weather data entry and analysis ▪ Develop algorithm for generating suggested system response to weather events ▪ Create visual interface into system data for TMC operator viewing / analysis ▪ Establish support systems to ensure data quality and resolve conflicting information
Level 4	▪ Define standard parameters and protocols for retrieving weather information from a variety of sources as automated inputs into decision support system ▪ Construct system architecture between automated data sources and decision support tool ▪ Develop interfaces to obtain traffic monitoring systems ▪ Develop algorithm to generate suggested responses based on a combination of weather patters and traffic monitoring systems
Level 5	▪ Develop a communications pathway to field devices to allow for automated responses to be implemented by decision support system
Procedural Dimension	
Level 1	▪ Ensure that TMC operators reacting to weather events on an ad-hoc basis do not overstep their authority or go beyond TMC procedures in implementing a specific response ▪ Develop a set of standard operating procedures for fine-tuning weather responses, including the recovery mechanism from an implemented ad-hoc response
Level 2	▪ Develop a set of pre-defined responses to specific weather events
Level 3	▪ Develop a standard set of triggers that would cause an operator to initiate use of the decision support system ▪ Develop standard rules and policies for implementing suggested response to weather triggers
Level 4	▪ Develop an "appropriateness" test for TMC operators to verify and utilize weather information data streams as inputs into decision support system ▪ Establish where weather responses fit within the hierarchy of traffic management responses ▪ Identify what traffic information is required to create appropriate traffic management responses to weather events
Level 5	▪ Develop a set of standard operating procedures for verification of implemented response and follow-up checking to insure appropriateness of response
Institutional Dimension	
Level 2	▪ Define operational procedures to allow TMC operators to provide coordinated response across jurisdictional boundaries ▪ Establish MOUs for inter-agency management / response plan
Level 3	▪ Develop inter-agency agreement to allow for the joint operation of traffic management infrastructure in the implementation of strategies to respond to weather events
Level 4	▪ Identify a funding stream for the ongoing operations and maintenance of weather information data streams as inputs into the decision support system
Level 5	▪ Obtain management buy-in / support of the use of a decision support system to effect / alter operations on the system as a result of specific weather triggers

* For all dimensions, requirements are described for the level of integration to which they first apply. If requirements are not mentioned for a higher level(s), then the last level mentioned is adequate for all the higher levels.

6.11 Item of Integration - Weather/Road Weather Data Acquisition

Data acquisition pertains to the level of technological sophistication used to process and manage weather data. The level of integration increases with greater data volume handling capabilities and as broader types of road weather information are incorporated in the TMC operations. This is usually a progression from a discrete level to a higher level and not necessarily an accumulation of all the individual components of the prior levels.

6.11.1 Strategies (or Levels of Integration)

Level 1 – Media Reports. Under this strategy, TMC operators will use traditional media outlets, such as local radio and television stations or cable stations, as their primary means to acquire information about road weather conditions that might effect traffic operations. Generally, these data sources will provide information on current and forecasted conditions as well as alert information for a wide area. TMC operators will not have control over when the weather information could be accessed, but must rely upon these media outlets to provide timely and accurate information about developing weather conditions.

Level 2 – Internet and/or satellite data sources. In this strategy, TMC operators will acquire road-weather information from Internet and/or satellite data sources. These sources can be from public or private weather information providers and will allow the operators to continuously monitor weather conditions. Using satellite and Internet sources, operators can obtain predictions of when weather events, such as snow and heavy rainfall, might arrive at specific locations.

Level 3 – Agency-wide intranet and dedicated phone acquisition.. With this strategy, TMC operators will access their weather information not only from external sources, but also from agency owned and operated weather monitoring stations to acquire road weather information. Weather monitoring devices will be installed at strategic locations and will allow the operator to access detailed weather information from specific locations. Depending upon the extent of coverage, information could be from scattered locations or an entire region or area. This level will require a more extensive communications network to bring back the weather information from the remote sensors to the TMC.

Level 4 – Dedicated communications link to state, federal, and private data sources. This strategy will involve constructing a direct link to other state, federal and private sources of road-weather information. Examples of these providers include the National Weather Service and other agencies. This might include securing a direct connection to the emergency management center where additional sources of roadway information might be available (for example, flood stream monitoring stations and other weather monitoring stations). Agencies could also subscribe to private weather information services that provide continuously updated weather information.

Agencies will need to configure their TMC software to support the integration of these data feeds into their TMC software systems.

Level 5 – Dedicated communications link to state, federal, and private data sources including vehicle-derived weather data. Under this strategy, the road weather information sources will be augmented with information obtained from probe vehicles or specially equipped vehicles. This might include private motorists, but is more likely to include special weather monitoring equipment installed in agency owned and operated vehicles (such as maintenance vehicles or snow plows). Vehicle-derived data could also potentially include video images. High bandwidth wireless communications will be required to transmit vehicle-derived data back to the TMC (especially if video will be transmitted).

6.11.2 Level of Complexity and Relative Costs

The following table describes the relative levels of complexity and costs across various levels of implementation of weather data acquisition.

Table 6.22 Relative Complexity and Cost of Implementing Different Levels for the Item of Integration - Weather/Road Weather Data Acquisition

Level of Integration	Description	Level of Complexity	Relative Cost
1	Media reports	Low	Low
2	Internet and/or satellite data sources	Low	Low
3	Agency-wide intranet and dedicated phone acquisition	Medium	Medium
4	Dedicated communications link to state, federal, and private data sources	High	Medium
5	Dedicated communications link to state, federal, and private data sources including vehicle-derived weather data	High	High

6.11.3 Requirements at Various Levels of Integration

Implementing any of the above strategies has a variety of impacts and requirements across the five dimensions of integration. Depending on the strategy or the level of integration selected from the list above, the table below identifies the requirements at various levels of implementation across all the dimensions.

Table 6.23 Requirements Across Five Integration Dimensions and Levels for the Item of Integration - Weather/Road Weather Data Acquisition *

Operational Dimension

Level 2	▪ Monitor weather information from additional sources, such as Internet or satellite data feeds ▪ Access weather forecasts / predictions on movement of weather systems ▪ Enable forecast / prediction information to be passed on to other TMC subsystems
Level 3	▪ Develop algorithms that monitor agency owned and operated weather information sources on a periodic basis
Level 4	▪ Develop algorithms that monitor external contracted information sources on a periodic basis
Level 5	▪ Develop algorithms that routinely monitor auxiliary information sources on a periodic basis

Table 6.23 Requirements Across Five Integration Dimensions and Levels for the Item of Integration - Weather/Road Weather Data Acquisition * (continued)

Physical Dimension	
Level 1	▪ Secure the ability to access traditional public radio or television feeds ▪ Equip TMC with devices to display television / radio feeds
Level 2	▪ Secure ability to access internet or satellite communications feed capability to access weather information ▪ Install terminal in TMC for displaying weather information ▪ Integrate internet weather feeds into TMC displays
Level 3	▪ Procure and install system of agency owned and operated weather information sources ▪ Integrate data feed with TMC software ▪ Provide an on-going communications capability to each information source
Level 4	▪ Provide an external connection capability of sufficient bandwidth to allow the agency to obtain private weather information source data
Level 5	▪ Procure and equip vehicle fleet with auxiliary mobile weather information sources ▪ Provide a communications pathway for mobile information sources to return information to TMC, via either roadside check-in points or mobile communication options such as cellular or satellite
Technical Dimension	
▪ Level 3	▪ Establish or adopt communications protocols for transmitting weather information ▪ Establish or adopt standard message sets for weather information transmission
▪ Level 4	▪ Develop interfaces to allow weather information to be integrated with TMC software
▪ Level 5	▪ Establish or adopt communications protocols for transmitting weather information on a mobile platform (including video if desired) ▪ Secure appropriate bandwidth providing mobile weather information source data from vehicle fleet ▪ Develop appropriate interfaces for integrated vehicle-based weather information into TMC software
Procedural Dimension	
Level 1	▪ Establish standard operating procedures that outline conditions and criteria to allow operators to actively monitor weather information from publicly available sources
Level 2	▪ Obtain access to additional information sources such as public internet feeds, private internet streams, or satellite information ▪ Set policies to allow operators to actively monitor weather information from these additional sources
Level 3	▪ Set policies on the use of agency specific field information sources
Level 5	▪ Set policies on the operation and use of mobile weather information sources on vehicle fleets
Institutional Dimension	
Level 2	▪ Provide funding to continue access to additional weather information sources
Level 3	▪ Provide funding to construct and maintain a field network of weather information sources
Level 4	▪ Provide funding to purchase and maintain dedicated weather information sources from external public or private suppliers
Level 5	▪ Provide funding to construct and maintain a mobile field network of auxiliary weather information sources on fleet vehicles

* For all dimensions, requirements are described for the level of integration to which they first apply. If requirements are not mentioned for a higher level(s), then the last level mentioned is adequate for all the higher levels.

PART III.

TMC
WEATHER INTEGRATION
PLANNING

Section 7. Developing a Weather Integration Plan

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

Many of the road weather management strategies described in Section 6 have associated uncertainties and risks during design, implementation, and operation. The U.S. Department of Transportation is a strong proponent of using the systems engineering approach to identify and evaluate alternatives, manage uncertainty and risk in systems, design quality, and handle program management issues that arise over the life cycle of any integration project[4]. TMC's should work with their regional system architecture developers and ,managers to ensure that the contents of the weather integration plan are consistent or updated in the regional architecture.

FHWA has developed a concept of operations for weather-responsive traffic management[5] that provides a framework of operation for transportation managers. The issues addressed include:

- How can transportation managers respond to weather-related events and provide information to both internal users and the public?
- How can transportation managers best utilize their resources to respond to weather-related events?
- What procedures and processes are needed by transportation managers to support weather-related activities?
- How should these procedures and processes be integrated with other transportation management activities?
- What additional resources are needed by transportation managers to support weather-related activities?

It is important to ensure that the weather integration plan developed as a result of the self-evaluation address the following four critical elements identified in the weather-responsive traffic management concept of operations.

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.

[4] ITS Joint Program Office, *Building Quality Intelligent Transportation Systems Through Systems Engineering,* Prepared by Mitretek Systems, April 2002.
[5] FHWA, *Weather-Responsive Traffic Management Concept of Operations,* prepared by Cambridge Systematics, January 10, 2003.

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.

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

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

- **Purpose and Benefit** -- An overview of the weather integration activity including its purpose, anticipated benefits, and the general process used to develop the integration plan.

- **TMC Overview** – An overview of the TMC and its responsibilities. Include a description of its regional operating environment, current and projected weather integration, and the factors that make weather integration important to its operations.

- **Weather Integration Self-Evaluation Process –** Briefly describe the process used to identify weather integration needs, priorities and strategies included in the weather integration plan. Describe the needs identified in the self-evaluation, why they are important to the TMC, and how they support the weather integration goals.

- **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.

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.

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

Concepts of Operations – Describe concepts of operations for management and decision-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.

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

Integration Solutions – Identify and discuss how the weather integration needs will be addressed by each of the strategies/solutions identified in 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 their TMC. These dimensions are defined in greater detail at the beginning of Section 6, and examples are provided for each item of integration throughout Section 6. 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.

Implementation of Integration Plan – Identify the activities that are required in order to implement the integration plan.

Integration Schedule (Phasing and Sequencing)

- **Implementation Timeframe** – Identify when the various TMC weather integration activities will be initiated and completed.

- **Sequencing of Strategy Implementation** – Describe how the strategies associated with each project will be sequenced and coordinated.

Cost Estimates – Provide estimates of the anticipated costs associated with the strategies identified in the integration plan.

- **Initial Costs** – Estimate costs of the hardware and software components needed.

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

Operations and Maintenance Requirements – Highlight the operations and maintenance requirements that will be needed to support the long-term operations and maintenance of the system, including consideration of staffing, support and training.

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

APPENDIX A.
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.

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.