Weather Responsive Traffic Management

New Approaches to Improve Safety and Mobility

Spring 2011, FHWA-JPO-11-093

Managing Weather Impacts in a Changing World

Adverse weather can change a routine trip to a life-changing event. Rain, snow, ice, and the like are partly or fully responsible for more than 1.5 million highway crashes, more than 600,000 injuries, and 7,000 fatalities on U.S. roads every year. Adverse weather is also the second leading cause of nonrecurring highway congestion, accounting for about 25 percent of delays. No wonder, when surveyed, travelers on our nation's highways clearly express the need for information on weather conditions (Figure 1).

While it is not possible to change the weather, it is possible to manage its impacts on the traveling public. Transportation operators view weather events as a significant challenge to their operations and developed effective approaches to manage their systems. Documented approaches range from simple flashing signs to coordinated traffic control strategies and regional traveler information systems. There is a need to increase the ability of system operators to provide safe and reliable transportation systems during bad weather.

In the last 10 years, new approaches, technologies, and strategies have emerged that hold great potential for Weather Responsive Traffic Management (WRTM), including Active Traffic Management (ATM) and Integrated Corridor Management (ICM). These approaches, along with new data sources and decision-support tools, offer opportunities for traffic operators to improve how they respond to and manage weather events. Access to quality-checked *Clarus* data and related applications open new avenues for WRTM, and the communication revolution and availability of mobile data provide new sources and formats for advisories beyond dynamic message signs, highway advisory radio, web sites, and 511.

These improvements will positively impact driver behavior. However, it is necessary to address the relationships between driver behavior and system impacts based on the strategy and the type of improvement as shown in Figure 2.

WRTM is at a tipping point. The need for it is clear. However, there are questions and challenges on how to move WRTM from an ad-hoc, local, reactive approach to an integrated, regional, and proactive model.

One challenge is the uncertainty along the linkages between weather conditions and traffic impacts. Research exists to understand the link between weather and traffic conditions, as well the benefits and impacts of WRTM strategies. However, transportation operators are not implementing a truly weather-responsive approach to traffic management partly due to skepticism on orchestrating a response based on weather forecasts.

Figure 1. Traveler Survey

Question: How important are each of the following features?

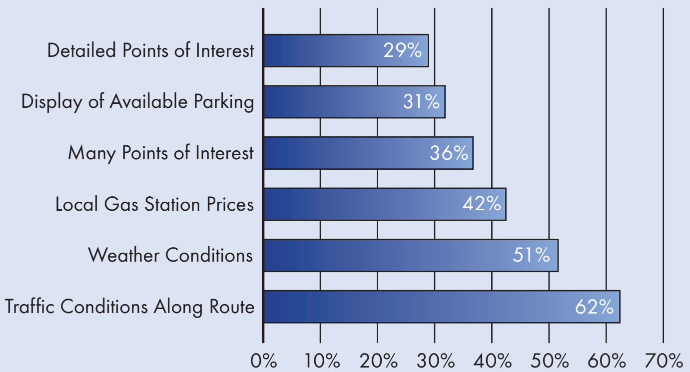
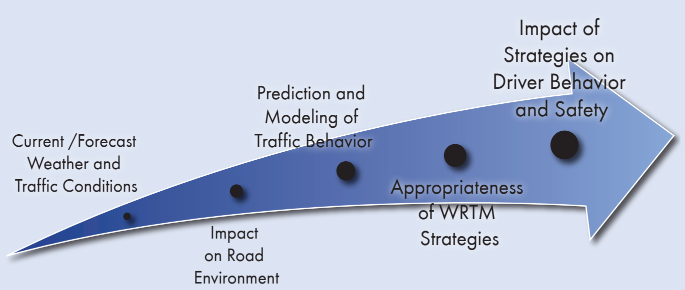


Figure 2. Driver Behavior and Weather



"Anytime, Anywhere Road Weather Information"

> **"The impact of weather on traffic flow isn't simple and straightforward. The effect on traffic can depend on the timing of the storm, when and how the roads are treated, and the temperature of the pavement. Sometimes, what seems to be a minor snowstorm can have a significant impact on traffic when there are a lot of minor incidents. At other times, moderate snow has virtually no effect."**
>
> *Dave Kinnecom*
> *Traffic Management Engineer*
> *Utah Department of Transportation*

The Federal Highway Administration's (FHWA) Road Weather Management Program (RWMP) is meeting this challenge. The RWMP is studying, developing, demonstrating, and implementing weather responsive traffic management solutions to improve traffic flow and operations during inclement weather, and minimize delays and crashes. Using a combination of advisory, control, and treatment strategies, the WRTM program provides real-world solutions to weather problems.

The RWMP established a coordinated roadmap of programmatic initiatives in an effort to help state departments of transportation (DOT) and affiliated agencies mitigate the adverse effects of weather. The WRTM program brings together strategies, research, human factors, and system performance in a logical framework for action.

Guidance, Tools, and Techniques

Consistent with the program framework, as shown in Figure 3, the RWMP has initiated and completed several activities under each of the components in the framework. State DOTs are evaluating a number of WRTM strategies to determine the safety and mobility benefits including the following:

- An evaluation of the Oregon DOT High Wind Warning Signs showed Benefit/Cost ratios of around 4 and 23 for the U.S. 101 and Yaquina Bay Bridge systems, respectively (*Kumar, M. and C. Strong, Comparative Evaluation of Automated Wind Warning Systems, Western Transportation Institute,* http://www.westerntransportationinstitute.org/documents/reports/426705_Final_Report.pdf).
- An evaluation of the effectiveness of the Snoqualmie Pass variable speed limit (VSL) system on I-90 in Washington showed that the system reduced average speed by up to 13 percent during unsafe driving conditions (*Washington DOT, 2002,* http://www.wsdot.wa.gov/research/reports/fullreports/511.2.pdf).
- The ITS Benefit Cost database reports low-visibility warning systems, such as those for fog warning, resulted in significant reductions in crash rates (*U.S. DOT, ITS-JPO, ITS Benefit-Cost Database,* http://www.itsbenefits.its.dot.gov/its/benecost.nsfSingleTax?OpenForm&Query=Road+Weather+Management).

The RWMP continues to review current practices, document the benefits of existing approaches, and identify needs, such as new or improved strategies for use on arterials and freeways.

In 2011, the RWMP developed a compendium of WRTM improvements in the publication *Developments in Weather Responsive Traffic Management Strategies (FHWA-JPO-011-086)*. The report details what strategies exist, where they have been used, the benefits realized, and how to improve, implement, and evaluate them. The result was the creation of five different WRTM strategy concepts of operations and high-level requirements as input to future system design. The development of guidance to agencies on evaluation approaches for several WRTM strategies offered supportable evidence of the performance and benefits of WRTM strategies and systems.

Traffic and Weather Data Collection and Integration

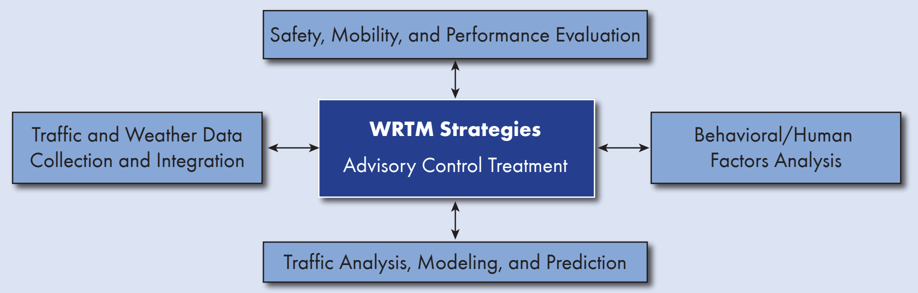
Without weather data coming into the transportation management centers (TMC), the ability to respond to weather is moot. Integrating high-quality, timely, and relevant weather information is a crucial component of WRTM.

Weather integration begins with understanding how weather impacts traffic in the TMC's jurisdiction, identifying high priority needs for better weather information, and implementing selected integration strategies that bring the relevant weather information to bear on operational systems for managing traffic and informing the public. TMCs can effectively integrate weather information by doing the following:

- Collecting, aggregating, analyzing, monitoring, and sharing traffic and road weather data collected from Environmental Sensor Stations (ESS) and other weather observing systems;
- Installing high-speed communications;
- Subscribing to value-added road weather forecast services; and
- Increasing technical and procedural connectivity, and using systems that support joint decision-making.

To support TMCs, the FHWA has been working for the past seven years on

Figure 3. WRTM Framework



understanding TMC needs and define the requirements for effective weather integration. The program has conducted a state-of-practice study and developed a framework for the types of weather and traffic data needed and how to integrate them to support effective operational strategies. To support the framework, a self-evaluation and planning guide was developed and implemented at various TMCs across the country. The following documents describe these activities:

- *Integration of Emergency and Weather Elements into Transportation Management Centers, FHWA-JPO-06-090;*
- *Weather Information Integration in Transportation Management Center (TMC) Operations, FHWA-JPO-11-058;*
- *Integration of Weather Information in Transportation Management Center Operations: Self-Evaluation and Planning Guide, FHWA-JPO-08-058; and*
- *Implementation and Evaluation of the Sacramento Regional Transportation Management Center Weather Alert Notification System, FHWA-JPO-10-063.*

Traffic Analysis, Modeling, and Prediction

Some of the questions the WRTM research is trying to address include what happens to traffic during weather events: is it possible to predict the impact of weather on traffic through analytical models, can these models be used proactively in real time to make traffic control and advisory decisions, and what tools are available to help agencies make those decisions?

FHWA works with researchers and universities to collect and analyze data and develop models and tools that can improve the analysis, modeling, and prediction of traffic flow under all types of weather conditions. Using data from Minneapolis-St. Paul, Seattle, and Baltimore, the RWMP conducted an empirical analysis of weather on traffic speed, capacity, and density; documenting results on the nature of speed and capacity reductions across the three metro areas.

From a microanalysis perspective, the RWMP is looking at individual driver responses to weather conditions, such as changing lanes, merging onto a freeway, making a left turn across traffic at an intersection, or adjusting the distance behind a lead vehicle. Using video tape data from intersections in Virginia and test tracks in Japan, the RWMP documented changes in gap-acceptance and car following behavior that could be vital in changing traffic control settings.

The goal of these studies is to inform model development and decision support tools that allow a user to translate current and forecast conditions to traffic impacts because traffic analysis models often do not include weather. The RWMP modified two Traffic Estimation and Prediction Systems (TrEPS) prototypes (DYNASMART-P, a system for transportation planning, and DYNASMART-X, a real-time system for predicting traffic conditions and patterns) to account for weather impacts, and improve traffic estimation and prediction capabilities and overall utility. These weather-sensitive TrEPS models are currently being calibrated and tested in four cities around the U.S. Information on these efforts is available in the following publications:

- *Empirical Studies on Traffic Flow in Inclement Weather, FHWA-HOP-07-073;*
- *Microscopic Analysis of Traffic Flow in Inclement Weather, FHWA-JPO-09-066;*
- *Incorporating Weather Impacts in Traffic Estimation and Prediction Systems, FHWA-JPO-09-065;*
- *Microscopic Analysis of Traffic Flow in Inclement Weather: Part 2, FHWA-JPO-11-020;*
- *Data Mining and Gap Analysis for WRTM Studies, FHWA-JPO-11-037; and*
- *Traffic Analysis Toolbox Volume XI: Weather and Traffic Analysis, Modeling and Simulation, FHWA-JPO-11-019.*

Behavioral/Human Factors

Unless the content, format, and timing of available weather information is consistent with what travelers need, want, and will use, then such information may not be useful and – in certain situations – may even lead to reduced mobility, as well as unsafe driving decisions and behavior.

In response, the RWMP recently developed a preliminary set of guidelines for road weather information communication and presentation (see Figure 4) that meet the needs of the drivers and travelers for different weather conditions and travel scenarios. Thirty detailed guidelines for road weather advisory and control information were developed. The guidelines are contained in a decision/design document, *(Human Factors Analysis of Road Weather Advisory and Control Information, FHWA-JPO-10-053*) that enables traffic managers to work through a series of questions to identify appropriate road weather messages and dissemination methods based on the type of weather event, anticipated mobility impacts, and the types of traveler decisions.

Safety, Mobility, and Performance Evaluation

Another challenge to WRTM adoption is the lack of documented benefits

"The FHWA weather integration self-evaluation process has had numerous benefits for the Wyoming Department of Transportation (WYDOT). The guide was very simple to use and it focused our attention on best practices. Such focus enabled us to concentrate our efforts and lend credence to our ITS requests when pursuing funding opportunities with WYDOT's executive staff."

Vince Garcia
GIS/ITS Program Manager
Wyoming DOT

necessary for state DOTs to invest time and resources to purchase and deploy system components and implement WRTM strategies. As state DOTs seek to apportion their scarce resources, they need assurance the benefits outweigh the costs for implementing a particular strategy. Evaluation measures and procedures that meet the needs of state DOTs and address national transportation goals are essential for WRTM to become a vital part of system operations (Figure 4).

Figure 4. Evaluation Measures

	WRTM Strategy (Broadly Defined)	Specific Strategy/ System Implementation	System Outputs	Expected Benefits/ Outcomes	Achievement of National ITS Goals
Pathway					
Example	Active Warning System	Automated system to warn travelers that ice may be present on a bridge at a specific location and to proceed with caution	Accuracy of warning relative to conditions Timeliness of warning Initiation Removal	Reduction in vehicle speeds Reduction in crashes, injuries, and fatalities Changes in driver perceptions of understanding and usefulness of the warnings	Improved safety Improved driver satisfaction

The RWMP recently developed evaluation guidance as part of the comprehensive review of WRTM describing a rational and practical approach to demonstrate the benefits of specific strategies. This information is contained in the *Developments in Weather Responsive Traffic Management Strategies, FHWA-JPO-011-086.*

In addition to providing guidance for performance measurement, the RWMP program conducted a thorough self-assessment to measure progress towards program goals specified in SAFETEA-LU. The assessment identified meaningful, understandable, and practical measures to evaluate products and activities produced as part of the program (*Road Weather Management Performance Metrics: Implementation and Assessment, FHWA-JPO-09-061*).

Connected Vehicle Research, Dynamic Mobility Applications

The world of traffic management has changed in response to the explosion of the scope and the capability of communication technologies enabling a previously unimaginable level of connectivity. Increasingly, mobile data gathered from individual vehicles are becoming viable for traffic management and modeling applications.

The ability to observe direct and inferred weather and road conditions from vehicles is still in development, and in the next 5 to 10 years, the WRTM program will look at new opportunities available through mobile data for improved weather and road condition products.

The RWMP also is actively involved in Connected Vehicle research within the U.S. DOT, championing weather-related applications as part of the overall ITS research program. Early applications related to weather are part of both the Safety and Mobility tracks in the Connected Vehicle research program. Additional information on road weather applications is available at http://www.its.dot.gov/factsheets/roadweather_factsheet.htm.

Research to Implementation

The RWMP has been a strong proponent of stakeholder outreach and participation as evidenced by the *Clarus* and Maintenance Decision Support System (MDSS) communities. Consistent with the broad nature of WRTM, the RWMP is continuing to work with partners across the traffic, weather, maintenance, research, and law enforcement communities. Parts of the WRTM program have seen the active participation of TMCs across the country, including six TMCs that conducted a self-evaluation of weather information integration needs. As a result four of the TMCs identified integration strategies they have begun to implement, and one of those implementations has been evaluated.

The stakeholder community has a vital role in WRTM moving to the next frontier. Just as a critical mass of stakeholders resulted in an active deployment of MDSS deployments and *Clarus* applications in the country, the stakeholder community is essential in the evolution of WRTM. From defining the direction of the program to testing, validating, and evaluating the new products emerging out of the program, the RWMP is looking for an engaged community to help provide real-world solutions to all-weather problems.

All photos and graphs courtesy of the RWMP.

U.S. Department of Transportation
Road Weather Management
1200 New Jersey Avenue, E86-205
Washington, DC 20590

Roemer M. Alfelor
202-366-9242
E-mail: roemer.alfelor@dot.gov
http://ops.fhwa.dot.gov/Weather/index.aps

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