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Road Weather Management Program Performance Metrics: Implementation and Assessment

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16. Abstract Since the late 1990's, the U.S. Department of Transportation (USDOT), Federal Highway Administration (FHWA) has managed a program dedicated to improving the safety, mobility and productivity of the nation's surface transportation modes by integrating meteorology into transportation operations and maintenance. Guided by goals in national legislation, FHWA's Road Weather Management Program (RWMP) seeks to improve the level of service on roads and reduce vehicle crashes through a combination of road weather research, scientific innovations to invigorate the private sector weather enterprise, and multifaceted education and outreach programs to engage public transportation agencies. The RWMP conducted a study with stakeholders from the transportation and meteorological communities to define eleven performance measures that will enable the USDOT to determine the extent to which these goals are being met. This report discusses these performance measures and presents results that illustrate the social, scientific and organizational benefits that can be attributed to the RWMP.			
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Acronym List

AMS	American Meteorological Society
ASOS	Automated Surface Observing Systems
ATIS	Advanced Traveler Information Systems
AWOS	Automated Weather Observing System
BASC	Board on Atmospheric Sciences and Climate
CARS	Condition Acquisition and Reporting System
CITE	Consortium for ITS Training and Education
COMET	Cooperative Program for Operational Meteorology, Education and Training
CVO	Commercial Vehicle Operations
DMS	Dynamic Message Signs
DOD	Department of Defense
DTN	Data Transmission Network
ESS	Environmental Sensor Station
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
HAR	Highway Advisory Radio ,
IIPS	Integrated Information and Processing Systems in Meteorology Conference
ITE	Institute for Transportation Engineers
ITS	Intelligent Transportation Systems
ITSA	Intelligent Transportation Systems America
ITS-JPO	Intelligent Transportation Systems Joint Program Office
LOS	Level of Service
MADIS	Meteorological Assimilation Data Ingest System
MDSS	Maintenance Decision Support System
MODSS	Maintenance and Operations Decision Support Systems
MOE	Measure of Effectiveness
MtDOT	Montana Department of Transportation
NCAR	National Center for Atmospheric Research
NDDOT	North Dakota Department of Transportation
NHC	National Hurricane Center
NHI	National Highway Institute
NHTSA	National Highway Traffic Safety Administration
NMVCCS	National Motor Vehicle Crash Causation Survey
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NWS	National Weather Service

OFCM	Office of the Federal Coordinator for Meteorological Services and Supporting Research
OHPI	Office of Highway Policy Information
PFS	Pooled Fund Study
PIARC	World Road Association
R&D	Research and Development
RFI	Request for Information
RFP	Request for Proposals
RISA	Regional Integrated Sciences and Assessments Program
RITA	Research Innovative and Technology Administration
RWM	Road Weather Management
RWMP	Road Weather Management Program
SAFETEA-LU	Safe, Accountable, Flexible, Efficient, Transportation Equity Act – A Legacy for Users
SCOM	AASHTO Subcommittee on Maintenance
SDDOT	South Dakota Department of Transportation
SICOP	Snow and Ice Cooperative Program
STWDSR	The Surface Transportation Weather Decision Support Requirements
TMC	Traffic Management Center
TRB	Transportation Research Board
UND	University of North Dakota
USDOT	United States Department of Transportation
USGS	United States Geological Survey
WIST	Weather Information for Surface Transportation
WRTM	Weather Responsive Traffic Management
WTI	Western Transportation Institute

Executive Summary

There is a concerted effort across the federal government to measure and track program performance. The development of an appropriate and manageable set of performance metrics is critical to the success of that effort. The Road Weather Management Program (RWMP) within the Office of Operations of the Federal Highway Administration (FHWA) at the U.S. Department of Transportation (USDOT) has been developing a set of performance metrics for its program since 2006. This report describes that effort and the results of applying metrics to evaluate its success against a set of goals established for the program.

Performance Measurement Goals

In 2005, the U.S. Congress passed the Safe, Accountable, Flexible, Efficient, Transportation Equity Act – A Legacy for Users (SAFETEA-LU) to fund the USDOT. Title V, Section 5308 of this act established a Road Weather Research and Development Program that has been managed by the RWMP. The RWMP's activities and services are guided by a set of goals that are specified in Section 5308 of the current SAFETEA-LU legislation. Three significant goals are defined in the legislation to guide RWMP research and development:

1. Maximize use of available road weather information and technologies;
2. Expand road weather research and development efforts to enhance roadway safety, capacity, and efficiency while minimizing environmental impacts; and
3. Promote technology transfer of effective road weather scientific and technological advances.

Section 5308 specifically cited the National Research Council report *Where the Weather Meets the Road*[1] as a source for programmatic recommendations to help guide the work of the RWMP in meeting the SAFETEA-LU goals. The RWMP responds to as many of these programmatic recommendations as possible within the limits of the available resources. To measure and interpret the social, scientific, and organizational benefits that accrue from these RWMP projects, activities and services, a challenge is to identify and implement reasonable performance measures that track the attainment or progress towards the SAFETEA-LU goals.

Measurement Framework and Approach

The objective in creating a set of performance metrics for the RWMP is to understand the accomplishments and benefits of the program, its products, activities and services in terms of its success in meeting the three SAFETEA-LU goals. Most of these effects can be measured as direct consequences of the RWMP, but some that are attributable to the RWMP may also result from indirect effects channeled through other stakeholders. One of the main elements of the RWMP program has been to foster a collaborative research and applications agenda in the field of road weather management. Other federal agencies, state agencies and the private sector

[1] National Research Council. *Where the Weather Meets the Road: A Research Agenda for Improving Road Weather Services*, 2004.

undertake activities independent of the RWMP that may affect progress toward achievement of the SAFETEA-LU goals. These activities can interact with the RWMP in a feedback loop that indirectly affects the performance of the RWMP's programs and activities.

In order to more fully understand RWMP performance, it will be important to look at more than a snapshot of the data that reflect the program's effect on the SAFETEA-LU goals. Progress toward goal achievement is expected to be incremental over time, and therefore, the selected metrics will need to be applied periodically, likely on an annual or bi-annual basis, to identify changes in RWM program performance.

The first step in identifying a manageable set of performance measures began with a literature review and a workshop with selected federal, state and private sector individuals knowledgeable about road weather and atmospheric weather, and experienced in developing performance metrics. A large list of candidate measures was widely distributed to over 250 national stakeholders who reviewed and commented upon the metrics, and offered their sense of program relevance and priority associated with each. This resulted in a refined short list of metrics that then were examined in greater detail, including more clearly defining each measure and specifying the data requirements to support each measure. The final report for Phase I describes the performance framework development process in more detail.[2]

These resulting 11 measures are shown in Table ES-1 under each of the 3 goal areas.

Table ES-1. RWMP Performance Measures

Goal 1: Maximize use of available road weather information and technologies.
1.1 Number or percentage of transportation agencies that use road weather information and decision support systems (based on current or forecast information) for making advisory, control and treatment decisions.
1.2 Number or percentage of travelers who use road weather information for making travel decisions (both pre-trip and en-route).
1.3 Number of environmental sensor stations (ESS) deployed and used by transportation agencies to support decision-making (normalized by total area or length of road network).
Goal 2: Expand road weather research and development efforts to enhance roadway safety, capacity and efficiency while minimizing environmental impacts.
2.1 Number of agencies participating in and benefiting from road weather R&D projects.
2.2 Percentage of time roadway meets safety and capacity level of service (LOS) standards (i.e. V/C ratio, etc.) during and after weather events (normalized by the frequency/intensity of winter events).
2.3 Reduction in agency costs (i.e. labor, equipment, and materials) due to adoption of maintenance and operations decision-support systems for road weather management.
2.4 Reduction in user costs (i.e. delay, crashes, vehicle operating costs, emissions, salt damage) due to improved road weather advisory, control and treatment strategies.

[2] U.S. Department of Transportation, Federal Highway Administration. *Road Weather Management Performance Metrics.* Report No. FHWA-JPO-08-039, 2008.

Goal 3: Promote technology transfer of effective road weather scientific and technological advances.
3.1 Number of agencies/individuals visited or contacted through technology transfer, training and outreach efforts.
3.2 Rate of adoption of RWM technologies (e.g., decision-support systems) by agencies that participated in workshop or training activities.
3.3 Number of RWM technology development, testing and deployment activities initiated through public or private sector based on identified operational needs.
3.4 Number of road weather technologies developed through public-private and/or public-public partnerships reaching operational deployment.

The RWMP addresses each of the three goals set forth under SAFETEA-LU by a combination of activities under four major objectives:

- Develop a national, open observing system that promotes data sharing to support weather observing and forecasting and transportation operations.
- Develop resources and training methods to assist state and local partners in deployment of weather management tools.
- Advance the state-of-the-practice by developing proactive solutions and disseminating information on adverse weather.
- Foster a collaborative, comprehensive, and dedicated surface transportation weather research program.

The RWMP has initiated several programs, projects and activities in the last five years. While each of these is at a different stage of project implementation, each has resulted in measurable outputs and outcomes for road weather management across the country. These accomplishments are expected to contribute directly to the attainment of the three SAFETEA-LU goals. In addition, the activities of the RWMP can serve as a catalyst to motivate and facilitate goal achievement through a variety of channels. For example, the RWMP sponsors workshops that inspire attendees to move in new directions with regard to more proactively incorporating weather into their own programs, and this in turn affects further progress toward achieving the SAFETEA-LU goals. The RWMP helps encourage the efforts of other federal agencies, state DOTs and private sector providers, and these other entities contribute to SAFTEA-LU goal achievement as well through their own independent initiatives and efforts.

RWMP Performance toward Achieving SAFETEA-LU Goals

Goal 1: Maximize use of available road weather information and technologies. The measures under Goal 1 primarily seek to address changes over time in the use of road weather information products and services. Deployment statistics data from 2004 to 2007 show increases in usage of road weather information in all aspects of operations.

- The number of states disseminating weather information to travelers has increased across various dissemination mechanisms from 2004 to 2007. In addition, the types of weather information disseminated have also substantially increased.

- A variety of control strategies were reported by states in 2007, ranging from 30 states reporting the use of technologies to manage diversions and closures during inclement weather to 5 states reporting the use of variable speed control during weather events.
- Since becoming a mature technology in 2005, the Maintenance Decision Support System (MDSS) has been utilized and tested by 30 agencies in 2008 in some manner with 5 agencies reporting operational use of an MDSS – a system intended to provide better information and decision-support to maintenance managers responsible for responding to winter weather conditions..
- Subscription to public and private road weather products and services has increased over the past three years.

The RWMP has had many direct and indirect contributions to the reported increase in use over the past three years by promoting the use of weather information in transportation operations around the country through a variety of activities including providing tools, conducting field tests and demonstrations, collaborating with private and public agencies for improved road weather information services, promoting best practices for weather information integration, weather-responsive traffic management, and development of the *Clarus* system and MDSS.

While increase in access and use has been clearly demonstrated, the quality and nature of use among agencies vary greatly and are uncertain from the deployment statistics. In other words, future performance measurement, in addition to tracking usage, needs to monitor quality of use when possible. The RWMP study on *Baselining Current Road Weather Information*[3] can provide valuable information in this regard in addition to specific deployment evaluations.

Goal 2: Expand road weather research and development efforts to enhance roadway safety, capacity and efficiency while minimizing environmental impacts. The four measures under Goal 2 seek to quantify the extent to which agencies are engaging in activities that will enhance the safety, capacity, and economic advantages of addressing the impacts of adverse weather conditions on roads and travelers, and do that while also minimizing impacts to the environment. National level trends reflect positively on RWMP performance. Although many of the best practices and new technologies being promoted by the RWMP have only recently become available, state transportation agencies are eagerly adopting them. Best practices have existed prior to the RMWP, and the RWMP has sought to compile, promote and catalyze increased adoption and use of these techniques. Clear results are difficult to quantify in this early and selective nature of the deployments but the evidence to date suggests significant use and benefits. At the local levels of deployment, RWMP tools, products and services and the best practices that the RWMP supports have resulted in wide-ranging benefits in terms of safety, mobility, efficiency, productivity and customer satisfaction. Monitoring levels of use coupled with project evaluations clearly indicate that RWMP programs are having real benefits under this Goal 2.

Goal 3: Promote technology transfer of effective road weather scientific and technological advances. The four measures under Goal 3 seek to quantify the extent to which the RWMP has been able to engage a wide range of stakeholders and potential users of road weather

[3] Federal Highway Administration. (2009), *Baselining Current Road Weather Information*. Final Report. FHWA-JPO-09-055. August.

technologies, communicate the benefits, promote usage, and successfully transfer operational tools and systems to states and agencies across the country. Measures of success include:

- Awareness and participation in the RWMP is very high among the states, and they report significant benefits from participation in the program.
- Participation in RWMP initiatives like *Clarus* and MDSS has continued to increase along with usage over the last four years.
- In-person and web-based training activities, road shows, and informational webinars sponsored by the RWMP are widely attended and appreciated.
- Close to 90 projects have been initiated in the area of Road Weather Management by private, public and academic groups that are involved with the RWMP.

Although indicated as the third goal of the RWM program, this goal reflects the first step in the process of raising awareness of the benefits of adopting RWM technologies and systems and directly contributes to the successes in Goal 1 and Goal 2. Much more progress along these lines can be expected in the future.

RWMP performance findings are summarized in Tables ES-2 to ES-4, and the available data have been collected either in direct support of each measure or indirectly through one or more indicators that are linked to the measure. The data vary in their ability to support the measure, and some of the indicators only offer weak linkage to their measure. These issues are discussed further in this report, and recommendations are made regarding future adjustments to the measures and indicators, as well as the need to identify new sources of data that can offer stronger support for the measures. Currently, the available data sources include the ITS-JPO Deployment Statistics and Benefit-Cost databases, RWMP program records, and transportation agency surveys and interviews conducted as part of this project.

The RWMP plays a variety of roles in its efforts to achieve the goals set for it under SAFETEA-LU, and these include initiating and implementing programs and projects that are designed to advance the frontiers of road weather research and development, providing training, engaging in partnerships and collaborative efforts, heightening awareness of the value of road weather information and its potential uses, and always seeking to encourage others to become more engaged in the application of road weather information and tools in support of advisory, control and treatment strategies in making our transportation systems safer and enhancing mobility. Both prior to the establishment of the RWMP, and since initiation of the range of activities and services described in this report, Federal, state and local agencies and the private sector have played, and will continue to play, a very significant role in the achievement of this program's goals. While this report has sought to highlight the performance of the RWMP as illustrated by the findings shown in Tables 13-15, the attainment of the SAFETEA-LU goals is ultimately a widely collaborative effort in which the RWMP plays a leadership role.

Table ES-2. Summarized Results for RWMP Performance Goal 1

Performance Measure	Indicators and Data that Support the Measure
Goal 1: Maximize use of available road weather information and technologies.	
1.1 Number or percentage of transportation agencies that use road weather information and decision support systems (based on current or forecast information) for making advisory, control and treatment decisions.	• The number of states providing travelers with weather information, using DMS, HAR, 511 or Web, increased on average 46% between 2004 and 2007. • States increased their dissemination of six specific types of weather information between 2004 and 2007 by an average of 49%. For example, 22 states reported providing route-specific weather forecasts in 2007, an increase of 69% over 2004. • In 2007, 46 states reported using atmospheric data and 45 states using pavement data for their operations, 30 states used ITS technologies to implement weather-related control strategies to manage road diversions or closures, and 15 states were using such strategies to implement temporary road restrictions. • MDSS usage has grown rapidly since 2004, and by 2008, 30 transportation agencies reported some use of MDSS, and five agencies reported operational use of MDSS to support winter maintenance operations. • Between 2004 and 2007 the number of state DOTs using weather information increased an average of 31%, with 45 state DOTs using NWS information, an increase of 29% over 2004 usage.
1.2 Number or percentage of travelers who use road weather information for making travel decisions (both pre-trip and en-route).	• In 2008, 33 states had 41 operating 511 systems, and 25 of those offered some type of road weather information. • On average, an estimated 12% of calls to 511 have accessed weather information.
1.3 Number of environmental sensor stations (ESS) deployed and used by transportation agencies to support decision-making (normalized by total area or length of road network).	• Between 2006 and 2008 the number of agencies contributing their ESS data to the *Clarus* System increased from 3 to 33, and these 33 agencies had 1,700 ESS reporting data to the *Clarus* System, which is about 68% of the national ESS deployed. • Between 2004 and 2007 the number of agencies providing ESS data for agency use increased from 26 to 30 (15%), and for public use from 38 to 45 (18%).

Table ES-3. Summarized Results for RWMP Performance Goal 2

Performance Measure	Indicators and Data that Support the Measure
Goal 2: Expand road weather research and development efforts to enhance roadway safety, capacity and efficiency while minimizing environmental impacts.	
2.1 Number of agencies participating in and benefiting from road weather R&D projects.	• Of 24 state agency respondents to interviews in 2009, 21 (88%) said they experienced moderate or substantial benefits (50% moderate and 38% substantial), and 20 of these respondents said they were involved in more than one RWMP activity.
2.2 Percentage of time roadway meets safety and capacity level of service (LOS) standards (i.e. V/C ratio, etc.) during and after weather events (normalized by the frequency/intensity of winter events).	• National level statistics do not exist yet to directly address this measure but interviews revealed that agencies are beginning to use performance measures to track safety and capacity level of service. • 32% of agency respondents interviewed in 2009 said they measure "time to wet/bare pavement." • 4% measure "percent of time that lanes are open during a weather event." • 7% measure "pavement friction measurements." • 11% measure "time to pre-event travel speeds after a weather event." • 18% measure "customer satisfaction with maintenance and recover time." • 25% use other performance indicators.
2.3 Reduction in agency costs (i.e. labor, equipment, and materials) due to adoption of maintenance and operations decision-support systems for road weather management.	• Between 2001 and 2007, nationwide costs for snow and ice removal ranged from $2.7 billion to $3.2 billion annually. • Selected evaluations of MDSS usage show savings by three states that range from $1.2 million to $1.7 million per winter. • A city maintenance unit saved $74,000 in shift labor costs in the 2008 winter. • Another state reported saving $12.1 million in salt usage and $1.4 million in overtime compensation from previous years. These correspond to a 41% reduction in salt usage and a 26% reduction in overtime compensation.
2.4 Reduction in user costs (i.e. delay, crashes, vehicle operating costs, emissions, salt damage) due to improved road weather advisory, control and treatment strategies.	• The RWMP encourages use of best practice technologies that reduce user costs due to weather and save lives. While these best practices may not have been developed by the RWMP, they are increasingly being used by transportation agencies and promoted by the RWMP as part of their program. • Fog warning systems have reduced crashes by 70 to 100%; RWIS use by up to 17%; anti-icing strategies by up to 83%; wet pavement detection by 39%; and conditions reported on DMS by 2.8%. • Low visibility warning systems reduced speed variability by 22% and increased speeds by 11%; HAR messages helped CVOs make better route choices; variable speed limits reduced average speed by 13%; weather-related signal timing reduced vehicle delay 8% and vehicle stops by more than 5%; and weather and road condition information on websites lead to increased traveler satisfaction (94% reported being better prepared and 56% reported it helped avoid delays due to weather).

Table ES-4. Summarized Results for RWMP Performance Goal 3

Performance Measure	Indicators and Data that Support the Measure
Goal 3: Promote technology transfer of effective road weather scientific and technological advances.	
3.1 Number of agencies/individuals visited or contacted through technology transfer, training and outreach efforts.	• Between 2004 and 2008, state DOT participation in annual *Clarus* stakeholder meetings promoted by the RWMP increased from 10 to 31 (68%). • Of 30 state agency representatives interviewed in 2009, 22 (73%) reported their agency was involved in the *Clarus* Initiative. • Between 2000 and 2008, 41 state DOTs have participated in one or more annual MDSS stakeholder meetings, and the participation level has remained stable. • Agency interviews in 2009 indicate 17 of 30 agencies (57%) are involved with MDSS and 13 of 30 agencies (43%) with both the *Clarus* Initiative and MDSS. • Agency interviewees reported deriving either "substantial benefits" (36%) or "moderate benefits" (48%) from their involvement in *Clarus* and MDSS, even though these are new programs. • The RWMP sponsored 6 road weather management training courses over the past several years that drew 151 attendees. An ITE course on *Fundamentals of Road Weather Management* had 40 participants in 2008, and the RWMP sponsored MDSS Road Show has been conducted 28 times between 2006 and 2008 with 925 participants across the country. • 22 out of 28 agency interviewees (79%) reported visiting the RWMP website, and 12 said they downloaded materials. 20 of 28 respondents (71%) said they participated in one of the NTOC webcasts.
3.2 Rate of adoption of RWM technologies (e.g., decision-support systems) by agencies that participated in workshop or training activities.	• Between 2006 and 2008, the number of state and local agencies contributing ESS data to the *Clarus* System increased from 3 to 33. • In the early deployment of the *Clarus* Initiative, 5 private sector entities are active users of *Clarus* System quality-checked data. • As noted under Measure 1.1, by 2008, 30 states and local agencies reported some use of MDSS, and five agencies reported operational use of MDSS to support winter maintenance operations.
3.3 Number of RWM technology development, testing and deployment activities initiated through public or private sector based on identified operational needs.	• Between 2001 and 2008 approximately 90 projects have been initiated through federal, state and university sponsorship with RWMP input and support.
3.4 Number of road weather technologies developed through public-private and/or public-public partnerships reaching operational deployment.	• Eight public-private and public-public partnerships supported by the RWMP are in various stages of operations across the country.

Multiple measures and indicators, supported by a variety of relevant data sources are required to look at all available evidence in assessing the RWMP's performance to date. This effort is only a first step to apply performance metrics in the RWMP. Applying these measures consistently over time will give a more complete picture of performance, particularly as the data improve and are collected more systematically for the purpose of supporting the metrics.

Conclusions

Performance measures offer a valuable tool to understand programmatic impacts, benefits, and potential for improvement. Stakeholders at the state and local level are eager to benefit from the activities, programs and services being offered by the FHWA Road Weather Management Program. At the same time, the RWMP is eager to see documented evidence that they are achieving the goals set out for the program and satisfying the needs of their customers. Reflecting early guidance from stakeholders, the eleven metrics examined in this paper are primarily directed at measuring the outcome benefits that the program is providing. But even the most carefully crafted performance measures can only approximate the concepts they seek to measure. The measures used to support the performance of the RWMP reflect a combination of quantifiable *outputs* (e.g., number of agencies that have acquired an MDSS, or the number of training programs conducted) and qualitative *outcomes* (e.g., the extent to which agencies are using MDSS more effectively throughout their jurisdiction, or the proactive incorporation of road weather information by transportation operators in decision making). In addition, other programs and factors can influence the measured outcomes, presenting a challenge to attribute observed data to the causal effects of the RWMP.

In addition, the responses of the state transportation agencies and stakeholders that are served by the RWMP offer another valuable indicator of program performance. State transportation agency stakeholders who were interviewed were asked to provide suggestions on how the RWMP could better support them. While a few respondents said they wanted more financial support from the RWMP, others sought more of what the program is already providing; namely, more opportunities to participate in programs such as the *Clarus* Initiative and MDSS, more long-distance learning opportunities and technology transfer given that states have severely constrained travel budgets, more direct engagement with the states in addition to channeling support through the private sector, and continued emphasis on ways to enhance and expand information flow and integrate weather into their operations. Overall, these stakeholders seemed pleased with the RWMP's performance, with one respondent saying, "Keep doing what you're doing."

Based on an enhanced understanding of its past performance, the RWMP will be in a position to more effectively move the quality and benefits of the program forward. Even with this first application of the measures, clear progress toward attaining the SAFETEA-LU goals has been demonstrated, and the future forecast for improving performance of the RWMP appears bright.

I. Introduction and Background

There is a concerted effort across the federal government to measure and track program performance. The development of an appropriate and manageable set of performance metrics is critical to the success of that effort. The Road Weather Management Program (RWMP), within the Office of Operations of the Federal Highway Administration (FHWA) at the U.S. Department of Transportation (USDOT), has been developing a set of performance metrics for its program since 2006. This report describes that effort and the results of applying metrics to measuring its performance against a set of goals established for the program.

Performance Measurement Goals

In 2005, the U.S. Congress passed the Safe, Accountable, Flexible, Efficient, Transportation Equity Act – A Legacy for Users (SAFETEA-LU) to fund the USDOT. Title V, Section 5308 of this act established a Road Weather Research and Development Program that has been managed by the RWMP. The RWMP's activities and services are guided by a set of goals that are specified in Section 5308 of the current SAFETEA-LU legislation. Three significant goals are defined in the legislation to guide RWMP research and development:

1. Maximize use of available road weather information and technologies;
2. Expand road weather research and development efforts to enhance roadway safety, capacity, and efficiency while minimizing environmental impacts; and
3. Promote technology transfer of effective road weather scientific and technological advances.

Section 5308 specifically cited the National Research Council report *Where the Weather Meets the Road*[4] as a source for programmatic recommendations to help guide the work of the RWMP in meeting the SAFETEA-LU goals. The RWMP responds to as many of these programmatic recommendations as possible within the limits of the available resources. To measure and interpret the social, scientific, and organizational benefits that accrue from these RWMP projects, activities and services, a challenge is to identify and implement reasonable performance measures that track the attainment or progress towards the SAFETEA-LU goals.

The RWMP contracted with a consultant team to identify potential output and outcome measures and select a reasonable and practical subset of those measures to quantify program performance. Eleven measures across the three goal areas were selected for implementation[5]. Data have been collected that reflect accomplishments through the implementation of a variety of RWMP activities undertaken in 2005-2009 to raise awareness, adoption and use of road weather information and technologies. These include, for example, the *Clarus* Initiative, Environmental Sensor Station Siting Guidelines, Maintenance Decision Support Systems (MDSS), Traffic Management Center Weather Integration, Vehicle Infrastructure Integration, and a number of

[4] National Research Council. 2004. *Where the Weather Meets the Road: A Research Agenda for Improving Road Weather Services.* Washington, D.C.: The National Academies Press.
[5] U.S. Department of Transportation, Federal Highway Administration. (2008). *Road Weather Management Performance Metrics*. Report No.: FHWA-JPO-08-039. EDL No.: 14420. (April).

other activities. These programs are intended to promote the use of road weather information in advisory, control, and treatment strategy decision-making supporting information to travelers, enhancing information and management systems for traffic operations, and improving weather-related decision support for highway maintenance activities.

The accomplishment and delivery of each of these program elements are intended to contribute to the attainment of the SAFETEA-LU goals. By measuring the progress towards the goal via the set of performance measures, and by attributing the impacts of the program elements to the attainment of these goals, the effectiveness of the RWMP can be assessed.

Measurement Framework

The objective in creating a set of performance metrics for the RWMP is to understand the accomplishments and benefits of the program, its products, activities and services in terms of its success in meeting the three SAFETEA-LU goals. Most of these effects can be measured as direct consequences of the RWMP, but some that are attributable to the RWMP may also result from indirect effects channeled through other stakeholders. One of the main RWMP program elements has been to foster a collaborative research and applications agenda in the field of road weather management. Other federal agencies, state agencies and the private sector undertake activities independent of the RWMP that may affect progress toward achievement of the SAFETEA-LU goals. These activities can interact with the RWMP in a feedback loop that indirectly affects the performance of the RWMP's programs and activities. Thus, the framework for establishing viable performance metrics is complex, since the pathways by which the RWMP affects performance outcomes are themselves complex. Figure 1 illustrates these elements of the framework. It shows that, in order to more fully understand RWMP performance, it will be important to look at more than one snapshot of the data that reflect the program's effect on the SAFETEA-LU goals. This will require a longitudinal assessment of how the RWMP's programs and activities are causing changes in key metrics and indicators over time.

Progress toward goal achievement is expected to be incremental over time, and therefore, the selected metrics will need to be applied periodically, perhaps on an annual or bi-annual basis, to identify changes in RWM program performance.

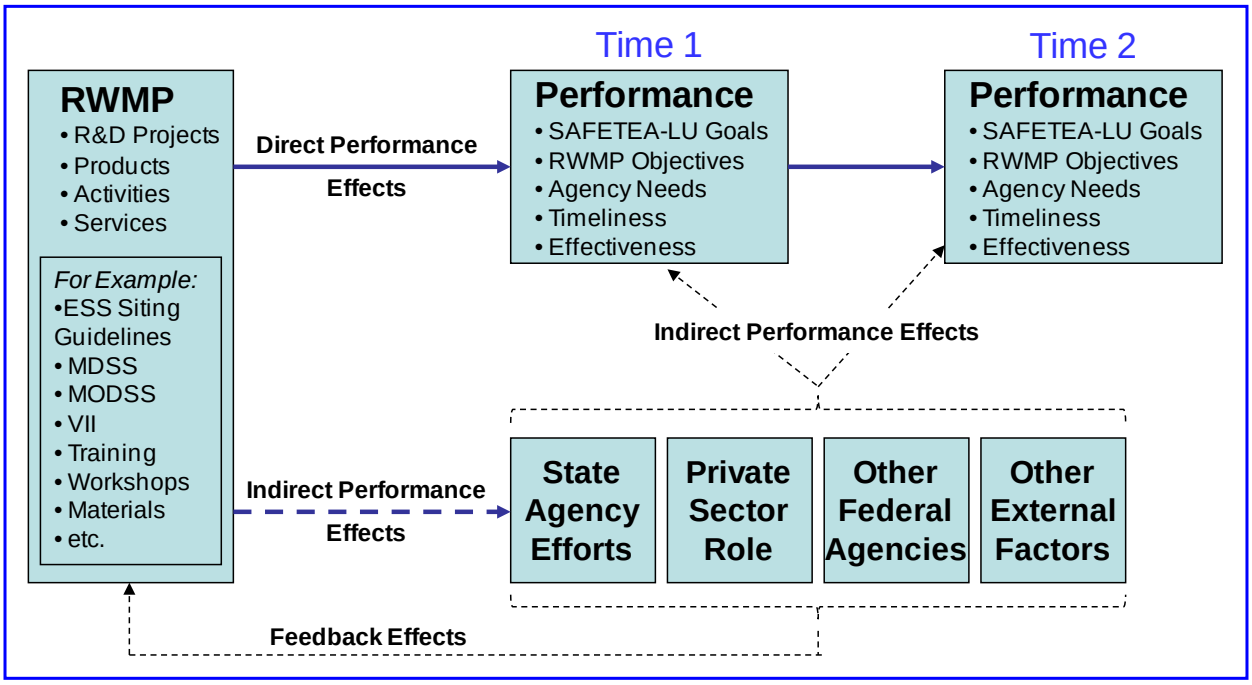

Figure 1. RWMP Performance Measurement Framework

Performance in this study is measured in terms of the RWMP's success in achieving each of the SAFETEA-LU goals. This is *not* an assessment of individual state Department of Transportation (DOT) performance in these areas. Each measure reflects strengths and weaknesses in terms of the efficiency and cost-effectiveness with which that measure can be operationalized, the data availability to support the measure, and the strength of the correlation of that measure with the goal performance it seeks to represent. The challenge presented by the presence of other external factors that also impact these goals is how to properly attribute attainment of the goal to the effects of the RWMP. An additional challenge is related to the early state of implementation of many of the RWMP's program activities; that is, many state DOTs have not yet begun to adopt and implement these program components and those that have are typically only partially implementing components at this time. Hence, data are not expected to be available to measure full performance against these goals in many instances.

The identified performance measures are of two basic types. *Output* measures are more quantitative indicators of operational efficiency, such as tons of materials applied to a freezing road surface or the miles of roadway plowed over a period of time. *Outcome* measures represent impacts or benefits achieved from program activities that tend to be more qualitative and difficult to assess, such as the value of reductions in travel time or travel costs that can be attributed to the use of a decision-support tool. Outputs link most directly back to the inputs, while outcomes relate more to the programmatic goals. Both output and outcome measures are essential in assessing program performance. The metrics selected for use in the RWMP combine elements of both output and outcome measures.

Approach to Identifying and Refining Metrics

The steps followed to identify a manageable set of metrics for assessing the RWMP are illustrated in Figure 2. These steps follow the process through to institutionalizing and refining performance metrics in the program over time, thus interpreting performance assessment as a continuing and evolving activity.

The first step in identifying a manageable set of performance measures began with a literature review and a workshop with selected federal, state and private sector individuals knowledgeable about road weather and atmospheric weather, and experienced in developing performance metrics. A large list of candidate measures was widely distributed to a national set of stakeholders who reviewed and commented upon the metrics, and offered their sense of program relevance and priority associated with each. This resulted in a refined short list of metrics that then were examined in greater detail, including more clearly defining each measure and specifying the data requirements to support each measure.

Literature Review and Synthesis

The literature review included over 150 documents pertaining to measures being used throughout the federal government and private sectors, including the National Oceanic and Atmospheric Administration (NOAA) and the Federal Aviation Administration.

The literature review concentrated on: 1) literature describing evaluations of traveler information, including Advanced Traveler Information Systems (ATIS) and 511 services as well as Road Weather Management (RWM) systems and services, 2) literature describing methods of evaluating traveler information and RWM systems and services, 3) literature describing control and treatment strategies and the metrics appropriate to measuring performance associated with associated RWMP activities, and 4) reports on the "valuation of information," as it applies to the economic benefits associated with RWM systems. Particular emphasis was placed on the outputs and outcomes of weather information on the following areas: traffic management (including traveler information), maintenance management, emergency management, transit management, transportation system performance, and driver performance.

The review examined the use of performance measures applied in other subject areas, for applicability to surface transportation weather programs. This included performance metrics currently used for products and services that are similar to RWMP products and services. Particular attention was placed on the NOAA National Weather Service's (NWS) Assessment Program and the NOAA Regional Integrated Sciences and Assessments program (RISA), since that agency has a long history of performance metrics development as part of its activity assessments.

The literature identified Measures of Effectiveness (MOEs) used by organizations and programs to assess attainment of their organizations' goals. The relationship of performance measures from similar programs and organizations was used to determine best practices, and the effectiveness of the performance measurement across programs and organizations was used to guide the selection of measures that would be likely to be useful for the RWMP.

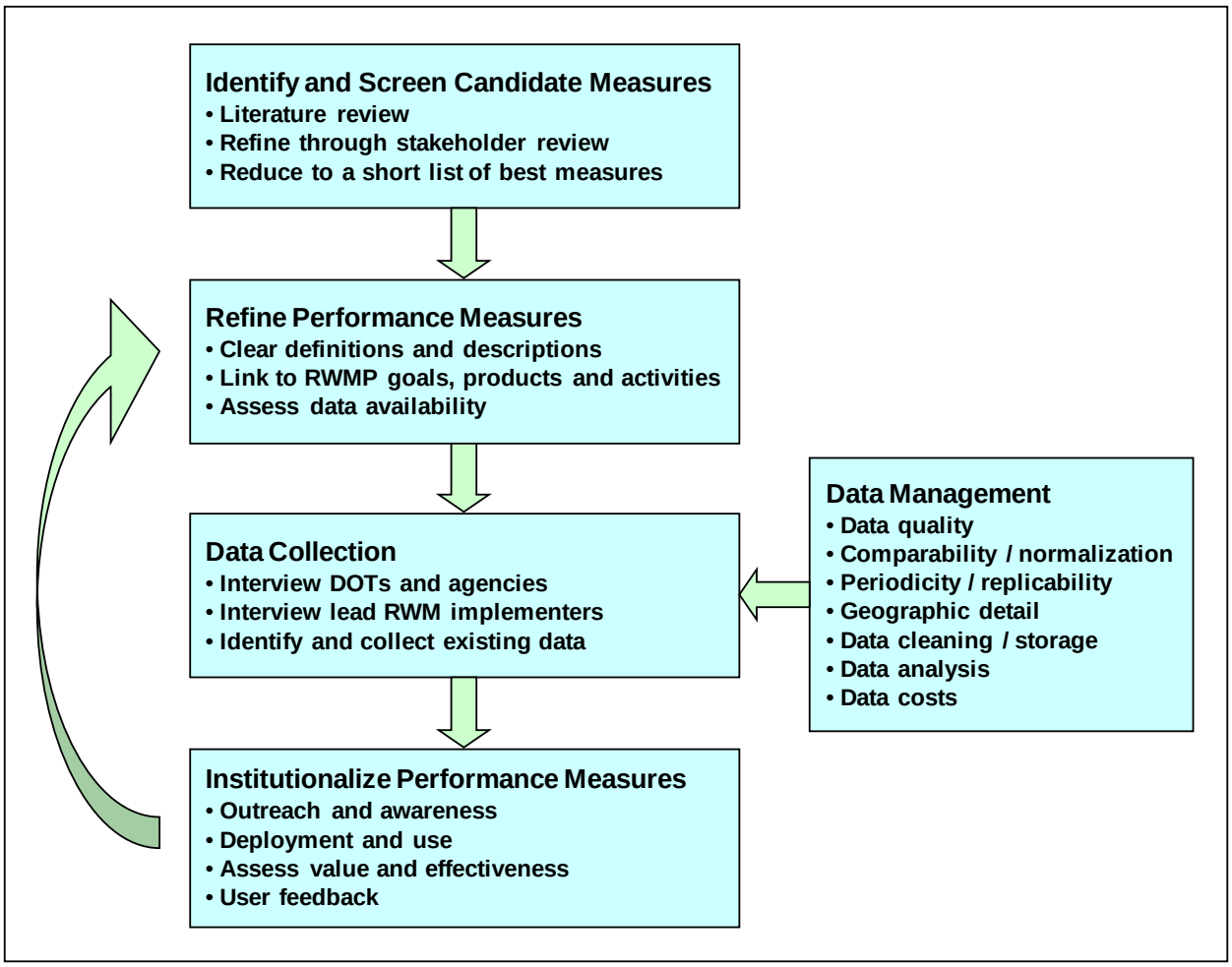

Figure 2. Flowchart of the Identification and Application of Performance Measures

Similarities and differences employed for performance metrics development and application across different programs were examined as a way to identify metrics that might be applicable to the RWMP. The review showed that the use of performance measurement is a well-established practice at both the State and Federal levels with continued expansion underway. The theme that pervaded the literature was the importance of performance metrics associated with safety, effectiveness, efficiency, and customer satisfaction. In addition, the process of performance measurement addresses fundamental questions of conciseness, ease of data collection, ease of interpretation, cost effectiveness, and validity of findings. Consideration is given to ensure that the process developed aims to continually improve programs through constant examination of outcomes and avoiding the pitfall of examining outputs only for program evaluation.

Each of the publications, reports and articles reviewed discussed efforts to assess performance in terms that could be classified into one or more of the following RWMP objectives:

- *Enhanced observation capabilities:* extended availability of weather observations through increased spatial coverage, number of observed weather elements and quality of observed data.
- *Advanced state-of-the-practice:* improvements in the implementation and operation of technologies and methods.
- *Coordinated research program:* enhanced management of research activities within agencies and across multiple agencies.
- *Training and outreach:* increased awareness of new knowledge or technology and methods for more effectively using technology through education.

This illustrates substantial consistency with the RWMP and its guiding SAFETEA-LU goals and provides a useful pathway toward selecting candidate metrics that would be suitable for assessing the performance of the RWMP. The measures identified in the literature were mapped to these four outcome categories, which facilitated compilation of the initial list of performance measures to then assess more carefully against the needs of the RWMP.

Stakeholder Review and Refinement of Preliminary Measures

Initially about 120 output and outcome measures were identified through the literature review. Next a workshop was held at which the preliminary measures were presented and discussed with USDOT personnel and selected stakeholders to obtain feedback and refine the measures before distributing them more widely for additional comment. The workshop was held with members of the RMWP team, representatives from other modes of the USDOT, NOAA, State Departments of Transportation, representatives of the Institute of Transportation Engineers and other stakeholders. An initial list of the draft measures was provided to the participants prior to the workshop. The comments and changes made at the workshop led to a reduced and refined set of about 65 measures that were then circulated on-line in the form of a Request for Information (RFI) survey to over 250 public and private sector stakeholders nation-wide for comments and recommendations. Respondents were identified from State DOTs, weather and road weather working groups, NOAA, and other agencies and individuals known to have an interest or involvement in the RWMP. These respondents included providers and users of road weather information, such as State DOT policy, maintenance, and operations personnel; transit (all modes) policy; maintenance and operations personnel; transportation and meteorological professional organizations; and other organizations cited in Section 4308(b) of SAFETEA-LU. The providers included both public agencies, who consume road weather information for their internal use as well as for delivery to the public, and private sector road weather service providers. The road weather information users included both public and commercial travelers.

Respondents were asked to indicate whether they thought each measure was “good” as is, “fair” and needed improvement, or “poor” and should be eliminated. They were asked to provide comments if they felt the metric needed improvement or should be dropped. They were also given the opportunity to add any new metrics that they thought were missing from the list. Out of this process, eleven measures were selected based on their relevance to the RWMP, endorsement by stakeholders, data availability, and ease of implementation. These 11 measures are shown in Table 1 under each of the 3 goal areas.

Table 1. RWMP Performance Measures

Goal 1: Maximize use of available road weather information and technologies.
1.1 Number or percentage of transportation agencies that use road weather information and decision support systems (based on current or forecast information) for making advisory, control and treatment decisions.
1.2 Number or percentage of travelers who use road weather information for making travel decisions (both pre-trip and en-route).
1.3 Number of environmental sensor stations (ESS) deployed and used by transportation agencies to support decision-making (normalized by total area or length of road network).
Goal 2: Expand road weather research and development efforts to enhance roadway safety, capacity and efficiency while minimizing environmental impacts.
2.1 Number of agencies participating in and benefiting from road weather R&D projects.
2.2 Percentage of time roadway meets safety and capacity level of service (LOS) standards (i.e. V/C ratio, etc.) during and after weather events (normalized by the frequency/intensity of winter events).
2.3 Reduction in agency costs (i.e. labor, equipment, and materials) due to adoption of maintenance and operations decision-support systems for road weather management.
2.4 Reduction in user costs (i.e. delay, crashes, vehicle operating costs, emissions, salt damage) due to improved road weather advisory, control and treatment strategies.
Goal 3: Promote technology transfer of effective road weather scientific and technological advances.
3.1 Number of agencies/individuals visited or contacted through technology transfer, training and outreach efforts.
3.2 Rate of adoption of RWM technologies (e.g., decision-support systems) by agencies that participated in workshop or training activities.
3.3 Number of RWM technology development, testing and deployment activities initiated through public or private sector based on identified operational needs.
3.4 Number of road weather technologies developed through public-private and/or public-public partnerships reaching operational deployment.

Most of the eleven measures shown in Table 1 are multi-dimensional, that is, performance in the measure is defined not by a single number but by a matrix of indicators. In order to effectively operationalize several of these measures using available data, selected indicators were identified that sought to support these various dimensions. For example, Measure 1.1 has associated with it four separate indicators. In a few instances, a data source can directly support the measure, such as with Measures 2.1 and 2.3.

Chapter II summarizes the programs, activities and services of the RWMP and the outputs and outcomes it seeks to accomplish. Then, Chapters III, IV and V discuss how these RWMP activities are directed to the attainment of each of the three SAFETEA-LU goals. For each of the performance measures and supporting indicators, direct and indirect effects of these RWM program activities are identified and data presented to illustrate, or "track", what that measure or indicator can tell us about program performance with regard to goal attainment.

Chapter VI provides an overview summary of the program performance that has been identified and tracked, and Chapter VII discusses the need to be forward-looking and the importance of conducting an annual assessment of changes in program performance over time in order to more fully capture the effectiveness of the RWMP in terms of goal attainment outcomes.

Finally, Chapter VII offers conclusions derived from the performance assessment conducted to date, fully recognizing that this is but a first step in a road weather program that in many respects has just begun to deploy its critical component project, activities and services.

II. RWMP Activity Summary

The RWMP addresses each of the three goals set forth under SAFETEA-LU by a combination of activities under four major objectives:

- Develop a national, open observing system that promotes data sharing to support weather observing and forecasting and transportation operations.
- Develop resources and training methods to assist state and local partners in deployment of weather management tools.
- Advance the state-of-the-practice by developing proactive solutions and disseminating information on adverse weather.
- Foster a collaborative, comprehensive, and dedicated surface transportation weather research program.

The RWMP was created more than a decade ago but in the last five years has initiated several programs, projects and activities in response to SAFETEA-LU. While each of these is at a different stage of project implementation, each has resulted in measurable outputs and outcomes for road weather management across the country. These accomplishments are expected to contribute directly to the attainment of the three SAFETEA-LU goals. In addition, the activities of the RWMP can serve as a catalyst to motivate and facilitate goal achievement through a variety of channels. For example, the RWMP sponsors workshops that inspire attendees to move in new directions in order to more proactively incorporate weather into their own programs, and this in turn affects further progress toward achieving the SAFETEA-LU goals. Figure 3 illustrates how performance measurement is directed at the outputs and outcomes of RWMP program elements.

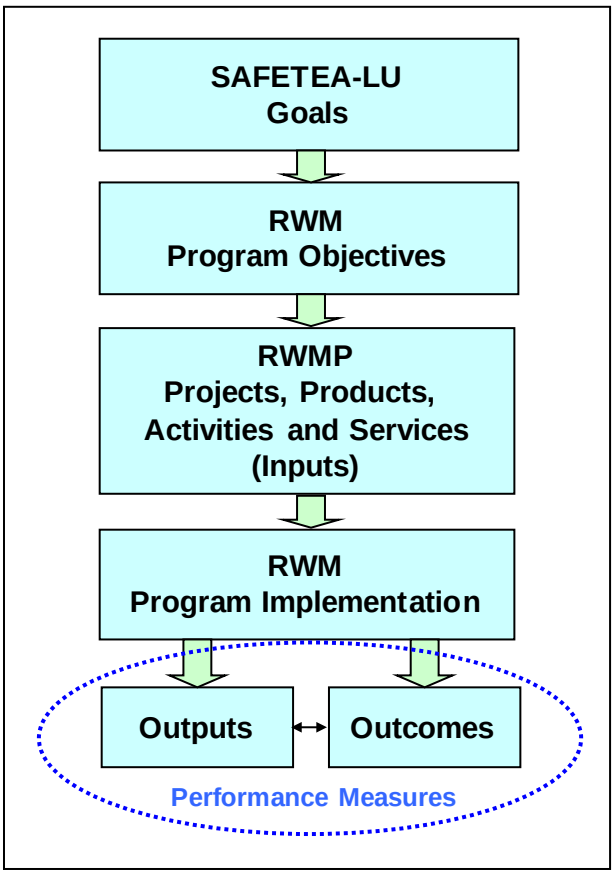

Figure 3. Role of RWMP Activities in Metrics Framework

Additional details on the outputs and outcomes associated with the RWMP and organized under the Program's four objectives are presented in Tables 2 to 5. These tables illustrate the depth and breadth of the projects, products, activities and services offered by the RWMP.

Table 2. RWMP Objective #1 – National Open Observing System

Programs	Outputs and Outcomes
WIST Initiative	• Raising awareness of issues relating weather to surface transportation (all forms) and vice versa. • Identification of surface transportation weather priorities to improve quality of services as part of each WIST meeting summary. • Identification of public (federal/state/local), private, and academic stakeholders.
COMET	• Fostered early relationship between NOAA (NWS) and the FHWA (RWMP). • Demonstrated method where NWS forecasts could be aided by use of ESS data. • Produced a NWS/Academic initiative to collaborate on research related to ESS data utilization including its assimilation with other surface weather data.
Cooperative Agreement between FHWA and NOAA	• Multi-year agreement between FHWA and NOAA on collaborative research on Road Weather Management.
Surface Weather Data Requirements for the National Highway System	• Identification of state and local agency ESS stakeholders. • Enumerated list of surface weather (primarily road weather) data requirements of stakeholders. • Dialog exchange among state/local stakeholders and the FHWA RWMP on uses of surface transportation weather and associated needs.
RWIS Standards – Siting, Calibration and Communication	• Defined a structured process and methodology for RWIS siting leading to improved ESS data quality. • Provided a checklist for achieving more effective ESS observation site operations. • Identified the plurality of ESS data usage (e.g., local operations vs. forecasting services) in resolving appropriate siting criteria.
Clarus Initiative	• Defines a national and several regional concepts of operation that present a holistic view of ESS data usage in the surface transportation and weather enterprises. • Established a prototype central (national) collection system for fixed and mobile ESS data from states and local agencies. • Established rules and methods of ESS data quality assurance and checking. • Promoted the collection and effective use of ESS metadata. • Fostered ESS data user stakeholder discussions primarily between state and local public agencies through (regular) national meetings. • Conduct demonstrations of ESS data use in enhancing surface transportation weather activities and operations (on-going activity).

Table 3. RWMP Objective #2 – Resources and Training Methods

Programs	Outputs and Outcomes
NHI Course on Road Weather Management	• Training resource to promote heightened awareness of the benefits of road weather management strategies. • Identification of strengths and weakness of present weather/road weather data observing and weather forecasting capabilities. • Characterization of difficulties in proper use of weather/road weather data and information. • Educational activities for sharing experiences in road weather utilization. • Reference guide that provides a compendium of road weather concepts, meteorological processes and weather information resources.
Snow Expo	• Display booth promoting activities, products, and training available from the FHWA RWMP. • RWMP presentations on efforts and accomplishments.

Programs	Outputs and Outcomes
Road Weather Resources Database	• Software resource for access and awareness of surface transportation weather literature. • Database of 600+ surface transportation weather published references.
MDSS Road Show	• Consolidation of market ready MDSS capabilities in the public and private sector. • Heightened awareness and understanding of MDSS technologies. • Fostering of current and potential MDSS stakeholder dialog.
Institute of Transportation Engineers (ITE)	• Developed and marketed a training course on Fundamentals of Road Weather Management that had over 40 participants.
ITS America	• Promoted the formation of 'Weather Alley' at ITS America and participated booth display promoting activities and accomplishments. • Presentation of conference papers citing accomplishment and activities of the RWMP. • Active participant on the ITSA Surface Transportation Weather Special Interest Group.
AMS	• Participation and past leadership of the AMS Standing Committee on ITS and Surface Transportation Weather. • Co-sponsor with AMS symposium on Surface Transportation Weather for the Integrated Information and Processing Systems in Meteorology Conference (IIPS). • Presentations on RWMP activities and accomplishments during IIPS conferences.
TRB	• Participation with the TRB Task Force on Surface Transportation Weather. • Conference presentations on RWMP activities and accomplishments.

Table 4. RWMP Objective #3 – Advancing the State of Practice

Programs	Outputs and Outcomes
Best Practices for RWM	• Collection of documented successful state and city uses of road weather management strategies. • Summary of best practices collated by management strategy types i.e. advisory, control, and treatment. • Keywords describing important/relevant aspects found within the Best Practices. • References to practitioners of best practices and their contact information.
MDSS	• Foster the growth of state and local agency interest in MDSS concepts and technologies. • Annual national stakeholder meetings to disseminate latest advances in MDSS and to promote winter maintenance community dialog on MDSS needs and practices. • Developed a functional prototype of MDSS server and client applications. • Developed a procurement specification guideline document for acquisition of MDSS services. • Conducted coordinated research and development utilizing various federal research laboratory resources and personnel. • Identified knowledge limitations requiring additional research. • In collaboration with the Weather Channel the RWMP produced a video on MDSS that was distributed on DVD and repeatedly aired on the Weather Channel.
Weather Responsive Traffic Management Strategies	• Identified through exploratory research with the Missouri DOT the management strategies most likely to support traffic management. • Conducted an evaluation of weather information integration into TMCs and developed a self-evaluation and integration planning guide for TMCs. • Developing, evaluating and helping deploy advisory, control and treatment strategies. • Currently working on development of statistical models and adjustment factors to account for weather impacts on speed, capacity and level of service. • Incorporating weather impacts into traffic modeling tools and traffic estimation and prediction systems.

Programs	Outputs and Outcomes
VII	• Conducted federal research to promote road weather methods using VII data. • Developed algorithms to extract road weather characteristics from VII data. • Advocated for road weather participation within VII. • Prepared scientific papers describing the benefits to road weather applications using VII.

Table 5. RWMP Objective #4 – Collaborative Research Agenda

Programs	Outputs and Outcomes
AMS Policy Forum	• Fostered collaboration between the surface transportation (FHWA) and weather (AMS) communities. • Produced proceedings documenting issues and benefits associated with the interaction between the weather and surface transportation professional communities. • Produced a list of priority issues needing attention.
TRB Surface Weather Task Force	• Created a forum for articulating issues of interest between weather and surface transportation professionals. • Formation of a TRB Standing Committee on Surface Transportation Weather (AH010).

Cooperative Research Programs	• Research performed on various topics, i.e., RWIS Testing Guidelines, etc.
	• Provided guidance on road weather research topics of interest.
	• Provided limited support to, helped guide, and cooperated with several national and regional research programs:
	  • Aurora RWIS Pooled Fund Program
	  • Clear Roads Program
	  • Snow and Ice Cooperative Program (SICOP)
	  • PIARC/World Road Congress
	  • AASHTO Subcommittee on Maintenance (SCOM)

Collaboration with NOAA, NCAR, OFCM	• Memorandum of Understanding between the AMS and ITS America. • Utilization of federal laboratories to conduct research and development. • Memorandum of Understanding between NOAA and FHWA for the development of surface transportation weather support, e.g., MADIS / *Clarus*.

III. Goal 1: Maximize Use of Available Road Weather Information and Technologies

The RWMP has been promoting the use of weather information in transportation operations around the country through a variety of activities including providing tools and promoting best practices for road weather information integration, weather-responsive traffic management, *Clarus* Initiative, the Maintenance Decision Support System (MDSS), and ESS Siting guidelines. These activities provide guidance, services, and tools to transportation operators to improve their advisory, control and treatment operations. The measures under this goal track usage of available road weather information for advisory, control and treatment by agencies and travelers and try to identify the direct and indirect effects of the RWMP program.

The three measures included under Goal 1 focus on changes over time in the number of users (including agency and end-users) of road weather information and the deployment of two key technologies (MDSS and ESS) used to support decision making. The data collected under the seven indicators all demonstrate significant increases in access to and use of road weather information over the past three years. There clearly remains room for further improvement in the use of available road weather information and technologies, and the activities and services of the RWMP are contributing toward the successful achievement of Goal 1.

Measure 1.1. Number or percentage of transportation agencies that use road weather information and decision support systems (based on current or forecast information) for making advisory, control and treatment decisions.

The use of road weather information by transportation agencies has existed in the United States since the 1970s. The growth in usage was stimulated in the early 1990s as the federal government, through the Surface Transportation and Uniform Relocation Assistance Act of 1987, made efforts to improve upon the use of road weather information systems and road weather service providers. The National Research Council's Strategic Highway Research Program conducted a milestone study that summarized the state-of-the-practice and made recommendations on installation of sensors and utilization of road weather in winter maintenance decision-making (SHRP-H-350 and SHRP-H-351). Subsequent to this effort only limited federal attention was given to road weather utilization until the formation of the RWMP in 1999 as a result of increase road weather attention provided through the FHWA Rural ITS program beginning in 1997. While numerous state transportation agencies were already engaged in road weather information and its use in advisory, control and treatment decision-making, the RWMP quickly became a focal point for a concerted national effort to raise awareness of the benefits of road weather information and the identification and promotion of road weather best practices. Since 1999, a wide array of studies, stakeholder meetings, research efforts, and awareness raising activities have been conducted to foster a broader utilization of road weather information in transportation agency decision-making through adoption and diffusion of technology and sharing of practices across the transportation agencies.

Some key activities to foster greater adoption and utilization of road weather practices within transportation agencies include the following:

- STWDSR/MDSS: The Surface Transportation Weather Decision Support Requirements (STWDSR) assessment program began in 1999 to identify, through broadly attended stakeholder meetings, the road weather requirements needed by transportation agencies. These meetings resulted in an action plan leading to the formation of the Maintenance Decision Support System (MDSS) in 2001. Development of the RWMP MDSS continues with major participation by the stakeholder community in annual meetings. These annual meetings have fostered broader transportation agency interest in the use of the MDSS to improve their road weather-related decision-making efforts.
- Road Weather Best Practices: A 2002 summary of successful road weather practices were compiled from across 23 states spanning over 30 case studies. These activities stress the benefits and application of advisory, control and treatment road weather management strategies that have served as a basis for many outreach activities presented to transportation agencies since 2002. While the best practices themselves were not necessarily a result of the efforts of the RWMP, the process of highlighting and promoting these efforts by the RWMP have resulted in greater awareness and further adoption by other transportation agencies.
- *Clarus* Initiative: The *Clarus* Initiative was begun in 2004 as an effort to define a more effective pathway for incorporating environmental sensor station (ESS) data into transportation agency operations and decision-making. The resulting *Clarus* System provides open access to a host of state-provided ESS data (including various Canadian provinces). Efforts currently are to demonstrate the benefits of the *Clarus* System through the design and demonstration of multi-state activities incorporating the ESS data from the *Clarus* System within transportation agency operations supporting advisory, control, and treatment actions. The *Clarus* System also promotes the use of ESS data through providing quality-checked data. The RWMP *Clarus* Initiative activities have included broadly attended stakeholder (or Initiative Coordinating Committee) meetings. These meetings not only have conveyed information on how to use the *Clarus* System, but also have solicited input and participation by the attending transportation agencies.
- Sponsor of NRC Board on Atmospheric Sciences and Climate (BASC) study: The FHWA RWMP requested the National Research Council to conduct a cross-cutting investigation of the state-of-the-practice of road weather and to identify a pathway for the future direction for the FHWA. This study was conducted by the BASC and included an assessment of practices and needs by the transportation agencies.
- Weather Responsive Traffic Management (WRTM) activities: The RWMP is involved in three major program tracks to promote greater utilization of road weather within traffic management.
    - Data Collection and Integration – The program has resulted in a self-evaluation and integration planning guide for improving the use of road weather information in traffic management operations and decision-making.
    - Weather-responsive Traffic Management Strategies – The RMWP is working with various states to implement advisory, control and treatment strategies to effectively manage traffic during weather.

- Understanding weather impacts on traffic flow – The RWMP is supporting development of statistical models, adjustment factors and microscopic traffic flow models. These studies will directly feed into planning and implementing appropriate WRTM strategies.

- FORETELL: FORETELL was the pre-cursor to the RWMP's first operational test with its award in 1997. The program was focused on bringing improved use of RWIS information along with better incorporation of weather forecasting into advanced traveler information systems (ATIS). FORETELL was one of the first road weather ATIS efforts and received considerable attention and scrutiny by the federal government and the transportation community. The program began as a three-state consortium along with a private sector contractor. Subsequent to the FORETELL program the consortium and private sector contractor have transformed the program into a larger ATIS program providing 511 and road condition reporting for numerous transportation agencies.

Ultimately, the above programs were intended to increase use at an agency-level. Measure 1 directly focuses on how many agencies are using road weather information for advisory, control and treatment decisions. There are four indicators that describe progress for this multi-dimensional measure:

1. Number of transportation agencies disseminating road weather information to travelers (advisory)
2. Number of transportation agencies using weather information for their operations (control)
3. Number of transportation agencies adopting MDSS technologies and methods (treatment)
4. Number of transportation agencies that subscribe to road weather products and services

Indicator 1: Number of transportation agencies disseminating weather information to travelers (advisory)

The first indicator supporting Measure 1 for this goal focuses on state DOTs providing road weather advisory information to travelers. Advisory information may include cautionary messages, weather advisories, travel times, accident reports, or routing and diversion information.

Direct Effects:

- Progress towards a national infostructure through the *Clarus* Initiative leading to higher quality road weather information around the country. The availability of such data is expected to improve advisory, control, and treatment strategies.
- Increase in use of road weather information in operations through the activities of WRTM. WRTM seeks to identify strategies for the effective integration of weather information in day-to-day TMC operations, and assist TMC managers and operators in developing and implementing advisory strategies for their agencies.
- RWMP has an important role in IntelliDrive^{SM} that will provide new sources of road weather information that may be used for road weather management strategies.

Indirect Effects:

- Increased awareness and interest at state DOT level of road weather information and management through operational tests and training activities.

- Exchange and documentation of best practices help transportation agencies provide better information to travelers.

Tracking this Indicator:
Tracking data were compiled from responses to specific weather-related questions posed in periodic surveys conducted by the USDOT Intelligent Transportation System (ITS) Joint Program Office (JPO) to measure ITS deployments in the United States. Figure 4 shows the number of states reporting that they provide advisory weather information as part of four different technologies including Dynamic Message Signs (DMS), Highway Advisory Radio (HAR), 511 phone system, and traveler information website in 2004 and 2007. An assumption was made that if agencies were disseminating information in 2004, they would continue to do so if there was no response from the state in 2007 for the survey. If there was no response in 2004, 2007 data were not used for comparison in the chart.

Across these four technologies, the number of states offering traveler information of all kinds increased somewhat (average 19% between 2004 and 2007 with the greatest increase in the number of 511 systems around the country), but the provision of weather information (indicated by the colored portion of the bars) increased 46% on average. The provision of weather information on DMS increased the most, about 84% over this three year period.

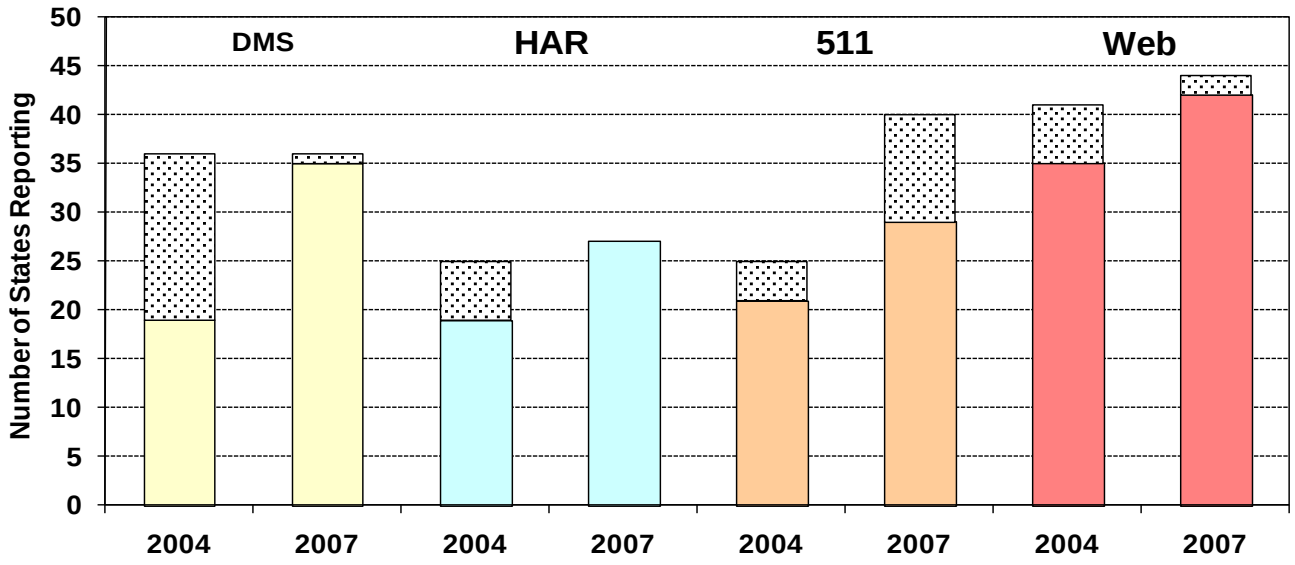

Figure 4. Indicator 1: Number of State agencies Disseminating Weather Information to Travelers, by Year and Technology[6]

However, the nature of weather information provided was not clearly identified in the above data and probably varies across the technologies and agencies. For example, DMS messages might vary from general weather advisories to specific route conditions. Weather information types that are being disseminated to travelers include:

[6] Survey Question – "Does your agency provide road weather information to the traveling public? If Yes, Please specify the type of dissemination system(s) (Check all that apply)."

- Atmospheric observations (e.g., precipitation and air temperature from ESS and airport observations)
- Atmospheric conditions (e.g., sky conditions, precipitation, wind speed/direction, and air temperature from analyses of observed weather data)
- Route-specific pavement condition data (e.g., dry, wet, plowed, flooded)
- Video images of selected routes
- Weather-related travel restrictions (e.g., tire chain requirements, closed routes)
- General weather advisories (e.g., National Weather Service watches and warnings)
- General weather forecast data (e.g., weather service provider generated weather forecasts)
- Route-specific road weather forecasts

Figure 5 shows there has been an increase in the types of data and information being disseminated across all information types between 2004 and 2007, with a 49% increase in all types of weather information being disseminated to travelers. Route-specific pavement condition information increased by 31%, and the provision of route-specific forecasts increased by 69% percent, although only 22 states reported providing this information and data in 2007.

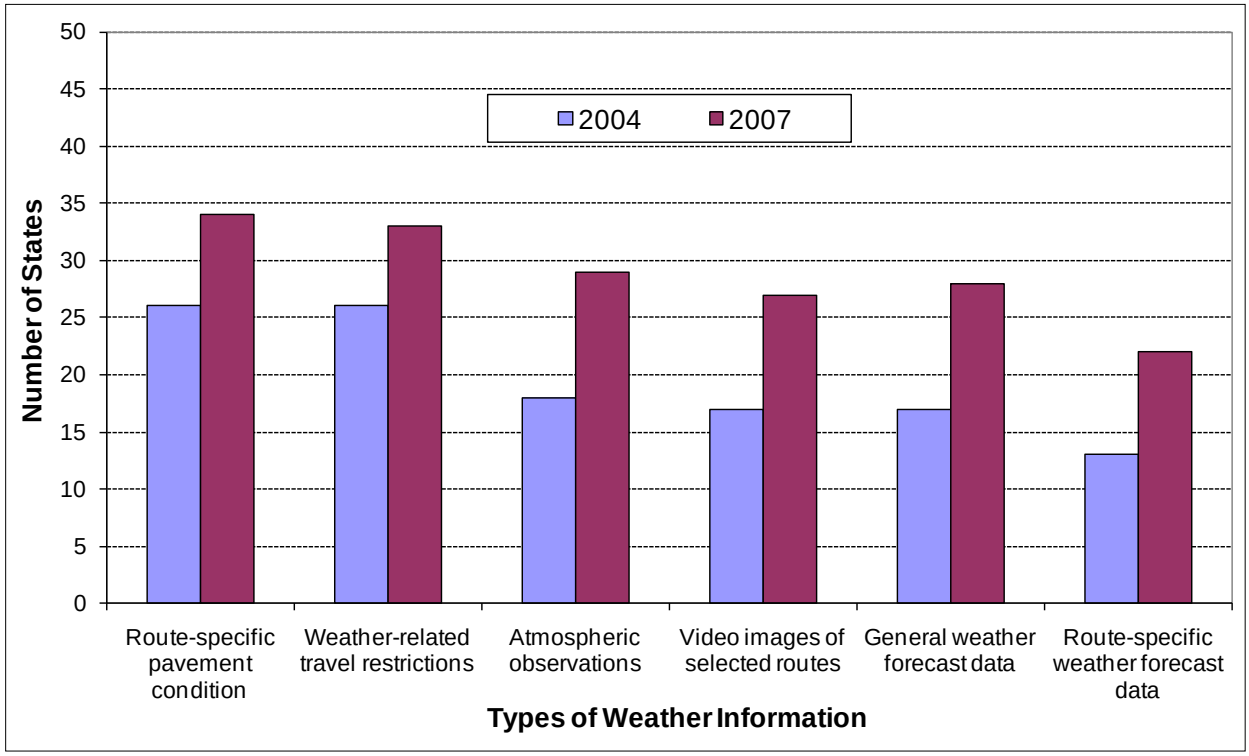

Figure 5. Number of States Disseminating Different Types of Weather Information: 2004 and 2007[7]

[7] Survey Question – "Please specify the type of road weather information disseminated to the traveling public (Check all that apply)."

Indicator 2: Number of transportation agencies using weather information for their operations (control)

The second indicator looks at the number of states using weather information, specifically atmospheric data and pavement-related data, to support their traffic operations.

Direct Effects:

- Through the WRTM program, RWMP is striving to improve the integration of road weather information in the day-to-day TMC operations, and assist TMC managers and operators in developing and implementing strategies for their agencies. The RMWP is developing, evaluating and deploying tools to analyze and effectively manage traffic during inclement weather, including the use of weather/traffic information to control traffic signals, ramp meters, and variable speed control signs. Some of these are being tested around the country.

Indirect Effects:

- The collection and dissemination of best practices has enabled agencies to understand different approaches to control traffic operations under inclement weather conditions.

Tracking this Indicator:

These data were also derived from the state surveys in ITS Deployment Statistics. In 2004, a large number of states were already reporting use of weather data in traffic operations by the transportation agencies in their states, so by 2007 only relatively small increases were possible in overall reported usage. In 2004, 44 states reported that atmospheric weather data (e.g., air temperature, precipitation, visibility distance) were used in operations and 41 states reported using pavement data (e.g., wet, freeze point temperature, chemical concentration etc)[8]. By 2007, 46 states were reporting use of atmospheric data and 45 states used pavement data for operations.

However, the method and rationale for use of weather information was unknown at an agency-level. Also not known was how widespread the use of such information is across the state responding to the survey.

While 2004 data were not available[9] and temporal comparisons cannot be made, in 2007, the ITS Deployment Statistics Survey reported states using a variety of weather-related control strategies (Figure 6).

[8] Survey Question – "What types of road weather information does your agency use to make operational decisions? (Check all that apply)."

[9] A corresponding question was not posed in the 2004 survey.

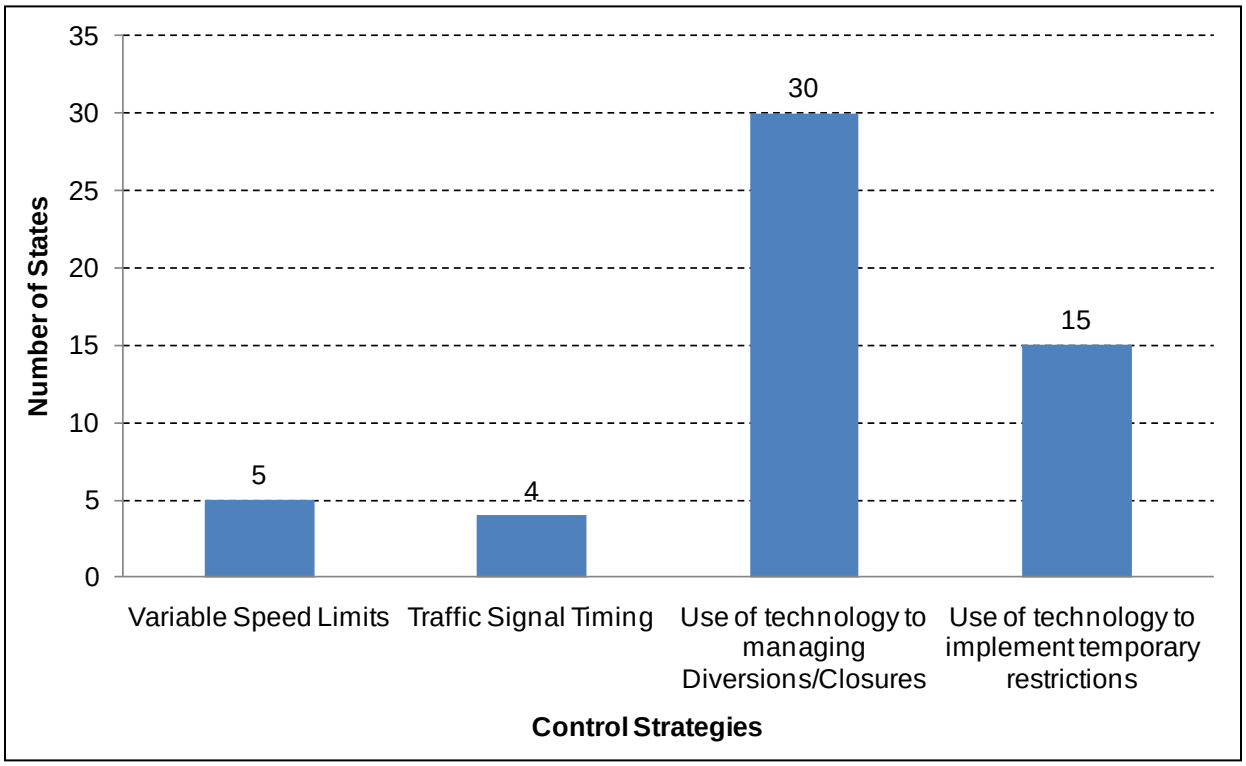

Figure 6. Indicator 2: States Reporting use of Weather Related Control Strategies in 2007[10]

Indicator 3: Number of agencies adopting MDSS technologies and methods (treatment)
The third indicator supporting Measure 1 is the number of agencies adopting MDSS technologies and methods to improve their treatment operations during winter weather events.

Direct Effects:

- Through the development of MDSS prototype and field testing of advanced decision support systems for use by winter road maintenance managers, the RWMP is having an impact on the use of such decision support systems. From 2002 to 2007, the RWMP MDSS prototype underwent five development cycles and three field demonstrations in Iowa and Colorado. The RWMP has offered free MDSS Road Shows and MDSS Product Demonstration Showcases for state DOT managers and field personnel resulting in increased awareness and usage.

[10] Survey Questions:

- "Does your state employ variable speed limits in response to weather conditions?"
- "Does your state change traffic signal timing in response to weather?"
- "Does your state deploy ITS technologies to manage traffic diversions in response to road closures due to weather events?"
- "Does your state employ ITS sensors to determine the need to implement temporary restrictions on vehicles during inclement weather conditions (e.g., road closures to high-profile vehicles during periods of high winds, snow tire/chain requirements during winter weather)?"

Indirect Effects:

- The RWMP has also supported the growth of MDSS through other forums and stakeholder meetings. A group of states initiated a Transportation Pooled Fund Research Project (pooled-fund study) in 2002 to develop and implement an operational MDSS customized for their agencies. The study is led by the South Dakota DOT and includes DOTs in California, Colorado, Idaho, Indiana, Iowa, Kansas, Kentucky, Minnesota, Pennslyvania, Nebraska, New Hampshire, New York, North Dakota, Virginia, and Wyoming. The states and their partners aim to create a sustainable, fully functional, scalable MDSS tailored to their tactical and strategic planning needs. Other private agencies have enhanced the federal RWMP prototype MDSS system with their value-added variants.

Tracking this Indicator:

2004 was the first year in which the RWMP advocated the adoption of MDSS technology. State DOTs that have adopted the MDSS also include those that have not yet implemented them, or have only used them in a limited deployment. By 2008, 30 state and local agencies were reporting some use of an MDSS, either in terms of partial geographic coverage or usage of only parts of the software system. Of those, five agencies reported operational use as part of their regular winter maintenance operations and decision support. Operational use means the system is being used as part of regular winter maintenance by the operational component of the agency to support decision making (see Figure 7).

Pooled Fund Deployment (Meridian Environmental Technology)

DTN/Meteorlogix (WeatherSentry subscribers with MDSS Winter Pavement Treatment Recommendations)

MDSS Usage	2004	2008
Some use of MDSS	0	30
Full operational use of MDSS	0	5

Figure 7. Indicator 3: MDSS Usage by States and by MDSS Provider (as of 2008)[11]

[11]Source: Figure and data from the RWMP, as of 2008.

Indicator 4: Number of transportation agencies that subscribe to road weather products and services

The fourth and last indicator used to operationalize Measure 1 examines the number of states with transportation agencies that subscribe to road weather products and services. These road weather products and services feed into all the advisory, control and treatment strategies.

Direct Effects:

- The RWMP has developed a TMC self-evaluation and planning guide to help agencies identify opportunities to use weather information in operations by mapping their operational needs to strategies for integrating road weather information.

Indirect Effects:

- Various sources of weather data are available to public agencies and the private sector. The RWMP has played a vital role in the coordination of road-weather information. Coordination with the National Weather Service (NWS) and the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM), has helped bring the needs of the transportation agencies to the forefront, thereby enabling the NWS and OFCM to help increase awareness of their products to the transportation community.

- The RWMP is working on road-weather sensing requirements for integration with various national weather sensing systems, enabling newer and more relevant road weather products and services that are offered through the public and the private sector.

Tracking this Measure:

Again the primary source of data was the ITS Deployment Statistics. Figure 8 shows the number of state DOTs that used weather information between 2004 and 2007 increased by an average of 31% with 45 state DOTs now utilizing National Weather Service (NWS) information, an increase of 29% from 2004. Thirteen (13) states in 2007 reported using airport observed weather products (e.g. ASOS, AWOS), an increase of 30% from 2004. Furthermore, 33 states subscribe to private-sector provided weather products, a 10% increase from 2004. These increases imply a heightened awareness of weather products along with the increasing relevance of these products in operations.

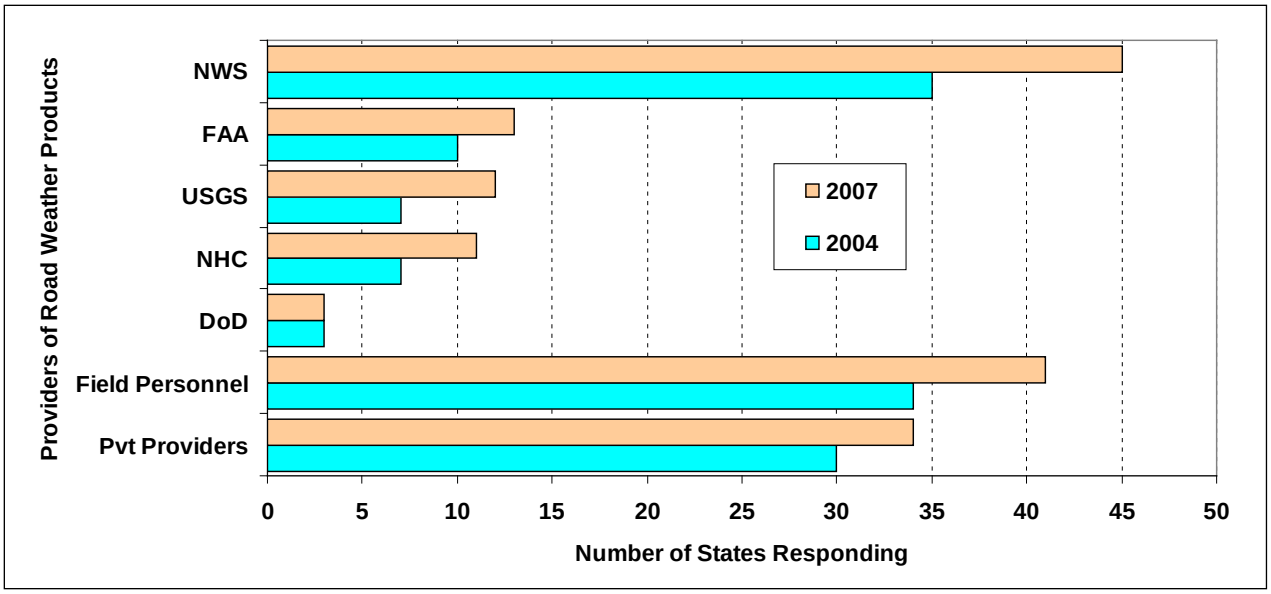

Figure 8. States that Subscribe to Road Weather Products and Services by Providers: 2004 and 2007[12]

Measure 1.2. Number of travelers using the transportation agency's 511 traveler information systems for weather information (volume of usage)

Advanced Traveler Information Systems (ATIS) have their origin in the early efforts of the Rural Intelligent Transportation Systems (ITS) concept that was promoted by the USDOT and the Intelligent Transportation Society of America. Rural ITS fostered the first statewide en-route traveler information systems, which incorporated road weather and road condition information as their central product. A Gallup poll conducted in 2001 indicated that weather information was the most highly valued and requested information from these statewide ATIS systems. However, most statewide ATIS systems (commonly 511 systems) do not include road weather information, and many do not even include atmospheric weather information. And while attempts have been made to foster greater use of road weather information within ATIS, the transportation agencies responsible for developing these systems often resist their inclusion, citing more pressing urban needs.

The key RWMP programs with direct and indirect effects addressed by this measure include:

- FORETELL: FORETELL was the precursor to the RWMP's first operational test with its award in 1997. The program was focused on bringing improved use of RWIS information along with better incorporation of weather forecasting into ATIS. FORETELL was one of the first road weather ATIS efforts, and it received considerable attention and scrutiny by the

[12] Survey Question – "What source(s) of weather information does your agency use to gather road weather information? (Check all that apply)"

federal government and the transportation community. The program began as a three-state consortium along with a private contractor. Subsequent to the FORETELL program the consortium and private contractor have transformed the program into a larger ATIS program providing 511 and road condition reporting for numerous transportation agencies.

- *Clarus* Initiative. The RWMP *Clarus* Initiative has as part of its multi-state regional demonstration a goal to promote the use of *Clarus* data in enhanced road weather traveler advisory information.
- Road Weather Best Practices: The RWMP 2002 summary of successful road weather practices included various traveler-related advisory and control practices. These activities included avalanche warning, flood warning, high wind warning, hurricane evacuation operations, low visibility warning, motorist warning, speed management, weather-related signal timing, and road weather information for travelers. While these practices were not necessarily the result of RWMP efforts, the RWMP serves as an active advocate for transportation agencies to adopt these practices for the benefit of travelers.

Measure 2 for Goal 1 looks at how many travelers are using road weather information for making their travel decisions. While traveler information systems may take on many formats, there are not many existing data sources that isolate the weather-related usage of traveler information systems. In addition, assessing whether the road weather information accessed by travelers in either a pre-trip or en-route situation is making an impact on their decision-making has long been a challenge. Similarly, while many transportation agencies host web pages that include weather and road weather information, these agencies often do not collect information on the effectiveness of these web pages. Only through interaction with the travelers or through inference drawn from usage statistics (or a combination of these) is it possible to understand how the information is being used by the traveler.

One indicator was selected for this measure, namely, the number of travelers' calls to states' 511 travel information phone systems and the number of those calls that were directed to weather information on those 511 systems.

Indicator 1: Number of travelers' calls to states' 511 travel information phone systems and the number of those calls that were directed to weather information on those 511 systems.

511 usage continues to grow and weather information is a part of several of these systems. However, weather-information on many of these systems is at a general level. In 2008, 33 states had 41 operating 511 systems, and 25 of those systems offered some form of weather or road weather information. No clear standards exist on what constitutes weather information on 511, although various resources exist. Very few states offer route-specific road weather condition information with most of the systems providing general weather or general road condition information.

Direct Effects:

- The RWMP has not directly supported the provision of road weather information on 511 traveler information systems but rather has been working with state and local agencies to

improve their overall advisory actions during weather events (511 is a major component of most state agencies' advisory actions).

Indirect Effects:

- From identification of best practices in Road Weather Management to development of a weather-responsive traffic management concept of operations, the RWMP has been encouraging agencies to share and disseminate weather and road weather information to travelers.
- In addition, the RMWP has sought to provide a common quality-checked platform for sharing ESS data through the *Clarus* Initiative, which can feed into state and local traveler information systems (an application is currently being developed and tested as part of the *Clarus* multi-state demonstration).

Tracking this Indicator:

Data for this indicator come from the 511 Deployment Coalition Database (as of June 2008), as well as the RWMP's *Baselining Current Road Weather Information* study. The 511 Deployment Coalition collects monthly usage statistics provided on a voluntary basis by the 511 system operators. Usage information collected includes call volumes per month and Interactive Voice Response (IVR) statistics such as call durations and category selections (one of which is Weather). Not all systems report all the data on usage, and category selection data is limited across the systems. Also, most of the systems report usage on the phone system and data are very sparse for 511-websites.

Twelve systems reported category selections as part of the IVR statistics of their 511 phone systems. Average IVR statistics (for an 8-month period – Sept 07 to March 08) vary widely with a low of 1% of calls seeking weather information to about 44.5% of calls seeking weather information. In addition to the twelve systems above, seven systems provide weather information to all callers who call into their system; that is, 100% of the calls receive weather information.

For all the 38 systems reporting call volume between the startup of their 511 systems and June 2008, an estimate of the percent of calls seeking weather information was derived using the IVR statistics above. When IVR statistics were not available for a system, the average percent across the 12 systems was used. Approximately 13 million of a total of 109 million calls since inception (or 12% of the overall calls) are estimated to be travelers' calls to 511 seeking weather information.

This estimated number of calls can be improved with continued reporting of usage over time by category selections by the 511 systems. The RWMP should work with the 511 Deployment Coalition to monitor monthly usage statistics collected by the Coalition to understand usage of the weather information on 511 websites. More broadly, given the varying nature of weather information on these systems, the RWMP should work with the 511 Deployment Coalition to endorse a broader incorporation of road weather in 511 systems and identify best practices and approaches.

Measure 1.3. Number of environmental sensor stations (ESS) deployed and used by transportation agencies to support decision-making (normalized by total area or length of road network).

The number of ESS deployed has been tracked by the FHWA RWMP for the past ten years, thereby providing an historical growth record over this period. At a basic level, the number of ESS deployed is a straight-forward measurement of road weather interest by state DOTs. The RWMP estimates that as of June 2008 there were 2,499 ESS of which 2,017 are part of a Road Weather Information System (RWIS). The remaining ESS are part of either localized agency use or not configured as part of a statewide network. Figure 9 shows the ESS deployments around the country in 2008.

While the growth in this number over the years is an important statistic, it can be misleading in several aspects. First, since many states have already deployed many ESS as shown on the map, the number of ESS in those states is not expected to increase substantially in the coming years. Second, it does not reveal the nature of the use of ESS.

The challenge of this measure falls into two distinct areas needing to be addressed: a) what is being done by transportation agencies to better use the ESS data available, and b) what has the RWMP done to promote the adoption of ESS technologies through increased deployment and utilization across state borders and within a given state. Developing a process to address the above questions will define the pathway to measure the RWMP performance.

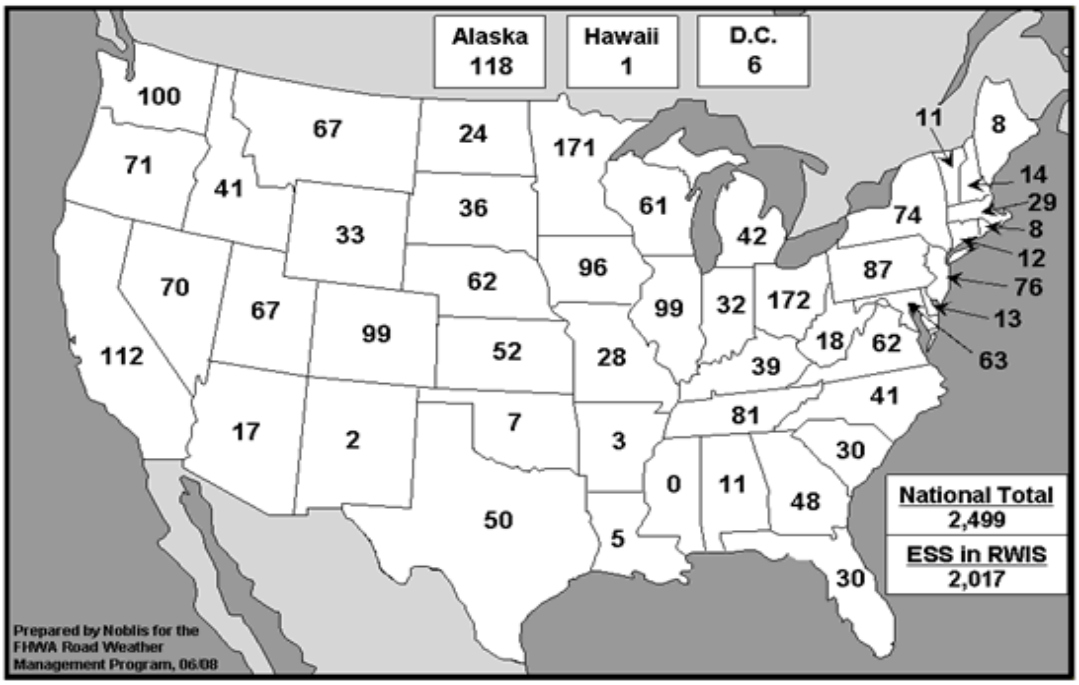

Figure 9. ESS Deployments in the United States:2008[13]

[13] Prepared by Noblis for the FHWA Road Weather Management Program, June 2008.

The RWMP has conducted various research programs, guideline development, and outreach efforts associated with ESS deployment and utilization. These include the following:

- ESS Siting Guideline (version 1 and version 2). Version 1 of the siting guidelines provided a documented approach to establishing siting criteria, instrumentation requirements and metadata development for ESS. This guide incorporated best practices from the weather community while addressing specific needs of the transportation agencies. Version 2 of the siting guideline included an evaluation study of the previous version and an update of the original guidelines to address deficiencies found through the evaluation and to incorporate new technologies that had emerged from the first version.

- *Clarus* System and *Clarus* Initiative. The FHWA efforts included a prototype for consolidating across North America the ESS data from transportation agencies. This effort included an in-depth stakeholder analysis and routine engagement of the stakeholder community (six national meetings to date) to develop a comprehensive user needs analysis. Subsequent development included a prototype ESS database system that included quality checking, which flows back to owner/operators of the ESS systems to provide quality assurance for the purpose of improved ESS data utilization. The *Clarus* Initiative is the final part of the effort that will engage the private sector surface transportation weather service providers to incorporate the quality checked *Clarus* System data to provide improved and new surface transportation weather services to transportation agencies and the traveling public.

- Outreach and Education Activities. The RWMP sponsored the development of a National Highway Institute (NHI) course to promote road weather management strategies. A significant part of this course is devoted to raising awareness of the purpose and use of ESS data, including the benefits provided by the *Clarus* System. This NHI course has resulted in additional Institute for Transportation Engineers (ITE) and Consortium for ITS Training and Education (CITE) courses that also promote the benefits of ESS data in agency decision-making. Also, as mentioned, six national *Clarus* stakeholder meetings have been held to present in a workshop forum the benefits and opportunities of better decision making using ESS.

Measure 3 examines the deployment of Environmental Sensor Stations (ESS) and their use by agencies to support their decision making. To capture the "use" element of the measure, three indicators were defined.

1. Number of transportation agencies contributing ESS data to *Clarus* System.
2. Number of transportation agencies providing ESS data via the web or other dissemination methods to support operational agency use and to provide general public access to the data.
3. Number of transportation agencies that have reviewed and used ESS Siting Guidelines.

Indicator 1: Number of transportation agencies contributing ESS data to Clarus System

The first indicator assesses the number of agencies that are contributing their ESS data to *Clarus.* A rapid increase in connectivity to the *Clarus* system reflects recognition of the value to agencies of having easy access to quality-controlled data from a variety of sources in their states and regions.

Direct Effects:

- Availability of *Clarus* System ESS data provides agencies with a source of quality-checked ESS information for their regions as well as adjacent regions of interest.

Indirect Effects:

- No indirect impacts identified.

Tracking this Indicator:
RWMP and *Clarus* System records show that between 2006 and 2008, the number of agencies contributing their ESS data to the *Clarus* System increased from 3 to 33. These 33 agencies had a total of 1,700 ESS reporting to the *Clarus* System as of the end of 2008, which is about 68% of the ESS in the country. Ten agencies are pending connection to the *Clarus* System, and another 8 are considering connection.

Indicator 2: Number of transportation agencies providing ESS data via the web or other dissemination methods to support operational agency use and to provide general public access to the data.
The second indicator for Measure 3 addresses the number of agencies providing ESS data via the web for both agency and public use.

Direct Effects:

- Availability of ESS siting guidelines enables public agencies to improve their utilization of ESS data in operations as well as traveler information by improving installation, operation and maintenance of ESS and RWIS. As part of the performance measurement, 39 representatives from state agencies were contacted in order to collect data for this indicator and other measures. Agency representatives who were interviewed were asked whether they have a copy of the ESS siting guidelines and, if so, have they used them. Of 20 who responded to this question, 18 (90%) said they had read the guidelines and 10 (50%) of them had used the guidelines either to support ESS installations or to review their current ESS usage plans.

Indirect Effects:

- None identified.

Tracking this Indicator:
Data for this indicator were from the ITS Deployment Statistics Survey similar to the other indicators in Measure 1. Between 2004 and 2007 the number of agencies providing ESS data for agency use increased from 26 to 30 (15%), and for public use from 38 to 45 (18%) as shown in Figure 10.

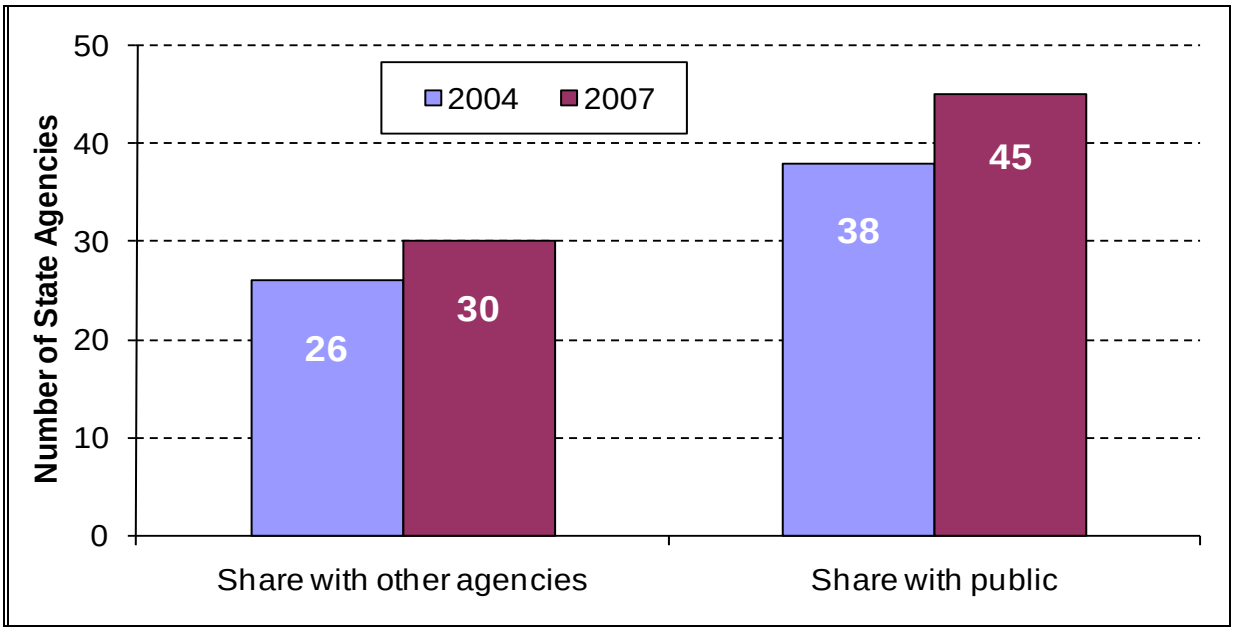

Figure 10. States Sharing ESS Data with Other Agencies and the Public[14]

[14] Survey Questions:

- "Select the entity or entities with which your agency shares ESS observational data. (Check all that apply)"
- "Please specify the type of road weather information disseminated to the traveling public (Check all that apply)
  Atmospheric observations (e.g., precipitation and air temperature from ESS)"

IV. Goal 2: Expand Road Weather Research and Development Efforts to Enhance Roadway Safety, Capacity and Efficiency while Minimizing Environmental Impacts

The four measures under Goal 2 seek to quantify the extent to which agencies are engaging in activities that will enhance the safety, capacity, and economic benefits of addressing the impacts of adverse weather conditions on roads and travelers, and do that while also minimizing impacts to the environment.

Since the RWMP is not a legislative body and does not create or enforce regulations, most of the effects of the RWMP with respect to this goal have been through the promotion of best practices and services. Although many of the best practices and new technologies being promoted by the RWMP have only recently become available, state transportation agencies are eagerly adopting them.

Best practices have existed prior to the RWMP, and the RWMP has sought to promote and catalyze increased adoption and use of these techniques. Clear results are difficult to quantify in this early stage of deployment but the evidence to date suggests significant use and benefits. As more state transportation agencies proactively adopt these advisory, treatment and control strategies, significant additional progress is virtually assured. The Goal 2 measures are important to quantify, and actions by state transportation agencies are the basis for assessing RWMP performance.

Measure 2.1. Number of agencies participating in and benefiting from road weather R&D projects

This measure tries to quantify the level of impact the RWMP is having at a state transportation agency-level in terms of the agency perspective, participation and perceived benefits of the RWMP program.

Direct Effects:
The RWMP has incorporated state transportation agency participation in demonstrations and pilot projects for a number of innovative road weather research areas. Some of these include weather responsive traffic management studies, road weather information system research involving the National Weather Service and universities, the *Clarus* Initiative including the development of a multi-state regional demonstration and a Connection Incentive Program, the demonstration of the federal prototype Maintenance Decision Support System in several states, the evaluation of RWIS ESS siting guidelines, and the integration of road weather within traffic management. Each of these activities has included agency participation during various aspects of the R&D project activities. For the demonstrations involving agency participation there is a direct benefit gained through agency personnel involvement. Where stakeholder meetings have been held, the agency benefits indirectly from the R&D project by their participation and

subsequent increased awareness of the technologies and results of applying these technologies. Through both the direct and indirect means, the level of benefit will also be modulated by the agency's acceptance of new ideas and technologies.

Indirect Effects:
Some of the benefits derived by the state DOT agencies from the road weather R&D projects are difficult to attribute to specific activities. This is because these benefits have been achieved by the RWMP championing the use of road weather information and technologies through such activities as training, outreach, demonstration projects, and best practices. The RWMP has fostered participation in road weather R&D projects through three primary means.

First, the RWMP has engaged the road weather community (i.e., stakeholder community) to participate in the discussion and review of R&D projects in order to maintain relevance with the road weather community and to develop agency champions to adopt the R&D project results. Second, the RWMP has conducted demonstrations and pilot programs that have directly involved the road weather community. The third approach has been to conduct research studies to assess road weather technology and identify best practices within the road weather community. The results of the latter two methods are often incorporated into the discussions and reviews for the first method.

Tracking this Measure:
As part of the assessment of performance measures, road weather stakeholders from state departments of transportation (DOT) agencies across the United States were contacted during the period of mid-May to mid-July 2009 (a list of individuals/agencies is available separately from this summary). Chosen for their knowledge of and involvement with the RWMP, 43 respondents were identified to contact. Thirty state agencies completed all or a portion of the interview. Two state agencies completed only a portion of the interview, citing a lack of road weather or road weather projects in their states. Nine agencies contacted via email did not complete the interview as they could not be reached by telephone. Three of the remaining four agencies were not contacted as the contact individual no longer worked for the DOT, while the last agency could not be reached via email to arrange an interview.

Figure 11 shows the benefits reported by agencies from the various activities of the RWM R&D program in which they are involved. Of the 24 respondents who reported involvement in one or more of the RWM programs, 21 (88%) said they experienced moderate or substantial benefits, with 50% noting moderate benefits and 38% noting substantial benefits. Three respondents indicated few benefits derived from the projects, and one indicated they did not know or were unsure. However, most of the respondents said they were involved in more than one RWM project (20 out of 24 respondents), and they offered comments to indicate which specific program they thought were particularly beneficial.

Each of these programs is relatively new, and agency involvement in many cases has just started. For this reason, a number of respondents said it was too early to know the level of benefit the agency can expect; therefore, at this point the respondents were more likely to report moderate benefits. Nevertheless, many mentioned they were pleased with what they had seen so far, and they thought these programs offered excellent potential benefit for their agency in the future.

One respondent mentioned that having access to ESS data from neighboring states has benefited their weather forecasts. Another respondent indicated that the quality control associated with the data is the largest anticipated benefit. An additional benefit seen by one respondent was substantial environmental benefits to accompany the financial benefits.

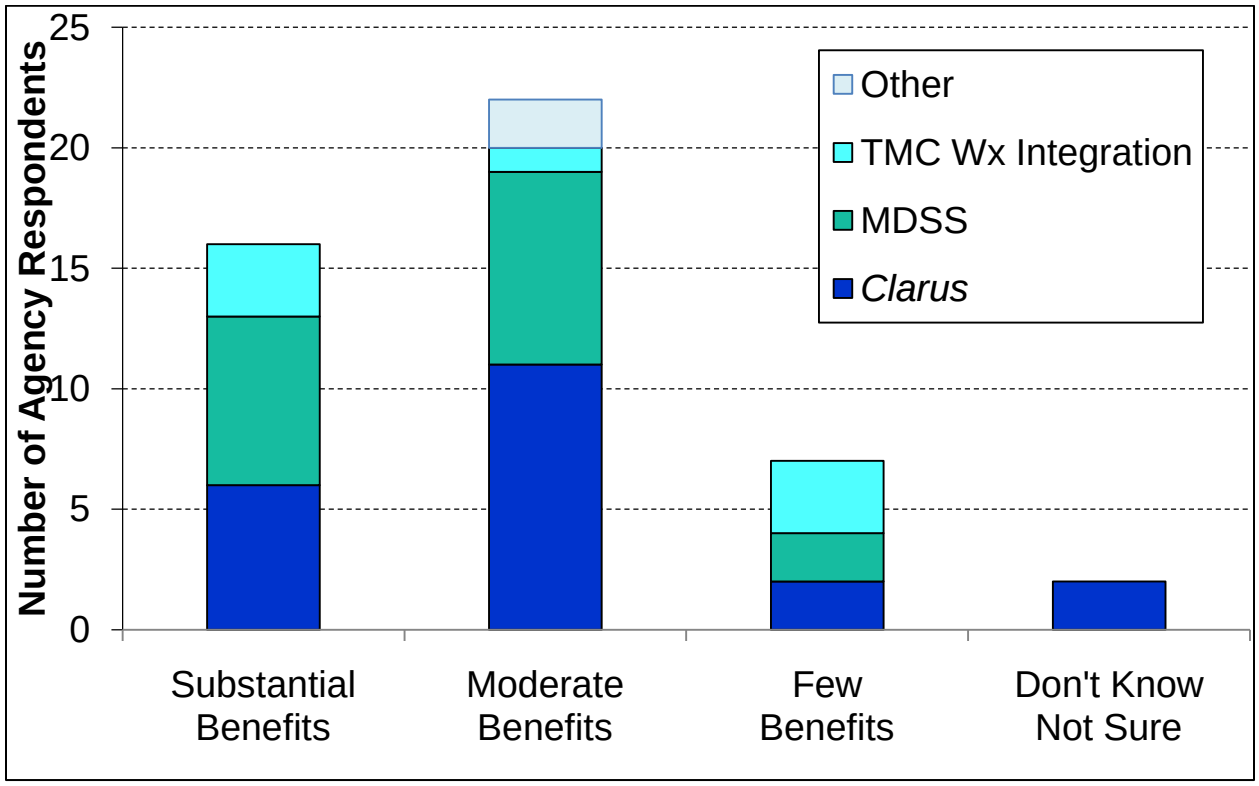

Figure 11. Assessment of Benefits of RWM Programs in Which Agencies Are Involved

Measure 2.2. Percentage of time roadway meets safety and capacity level of service (LOS) standards (i.e. V/C ratio, etc.) during and after weather events (normalized by the frequency/intensity of winter events)

The impact of weather events on roadway safety and capacity is substantial. For example, Stern et al[15] analyzed weather data and travel time data using regression and means analysis for the Washington D.C metropolitan area. They estimated that the average impact of precipitation on peak-period traffic was at least an 11% increase in travel time with a high likelihood of the

15 Andrew D. Stern*, Vaishali Shah, and Lynette Goodwin, Paul Pisano, *Analysis of Weather Impacts on Traffic Flow in Metropolitan Washington DC,* American Meteorological Society, 2003.

impact being closer to a 25% increase in travel time. Also, Agarwal et al[16] quantified the impact of rain, snow, and various pavement surface conditions on freeway traffic flow for the metro freeway region around the Twin Cities using detector data, automated surface observing systems (ASOS) at nearby airports, and ESS in close proximity to the freeway system. The study indicated that severe rain and snow caused the most significant reductions in capacity and operating speed. Heavy rains (more than 0.25 inch/hour) and heavy snow (more than 0.5 inch/hour) showed capacity reductions of 10%–17% and 19%–27% and speed reductions of 4%–7% and 11%–15%, respectively. The study also quoted several weather impact-related research studies that showed that the slightest amount of precipitation (also called a trace amount) either in the form of rain or snow reduces capacity in varying degrees. Similar significant impacts were found by other studies (Knapp et al[17], Goodwin[18], and FHWA[19]).

The RWMP is significantly directed towards minimizing the safety and capacity impacts of weather events primarily through dissemination of best practices in road weather management, to better treatment strategies through MDSS, advanced weather notification and alert systems, and weather-responsive traffic management, the RWMP has tried to link weather information to operations with the goal of minimizing safety and capacity impacts.

Direct Effects:

- The WRTM program is directly positioned to improve transportation agency response during weather events. Through supporting deployment and evaluating strategies for proactive management of weather impacts on traffic, the RWMP seeks to reduce loss of capacity and exposure to unsafe driving conditions. Currently, the WRTM program is in an early phase of deployment.

Indirect Effects:

- As public agencies adopt the RWMP-developed decision-support tools like MDSS and MODSS, increased efficiencies in maintenance and operations activities will affect this measure. For example, quicker and more effective treatment of pavements enabled by MDSS during weather events might result in improved capacity and level of service.

Tracking this Measure:

It is difficult to identify specific measures that document RWMP influence on safety and capacity, as the primary role of the RWMP as a catalyst of the WRTM program is in its early stages. Currently, the RWMP has enabled and continues to strive for a culture shift among traffic operators to a more proactive weather management approach that in turn will improve safety and capacity. The RWMP also has completed or is currently undertaking studies relevant to safety, including studies of the microscopic and macroscopic behavior of traffic in inclement weather

[16] Impact Manish Agarwal, Thomas H. Maze, anf Reginald Souleyrette, *Impact of Weather on Urban Freeway Traffic Flow Characteristics and Facility Capacity*, Sponsored by the Aurora and the Midwest Transportation Consortium, Iowa State University, Center for Transportation Research and Education, 2005.
[17] Keith K. Knapp, Leland D. Smithson, and Aemal J. Khattak, *The Mobility and Safety Impacts of Winter Storm Events in a Freeway Environment*, Iowa State University, Center for Transportation Research and Education, 2000.
[18] Lynette C. Goodwin, *Weather Impacts on Arterial Traffic Flow*, December 24, 2002.
[19] USDOT, FHWA. *Empirical Studies on Traffic Flow in Inclement Weather.* Report No. FHWA-HOP-07-073, 2006.

conditions, weather-sensitive traffic prediction and estimation modeling, and evaluation of the effectiveness and safety implications of road weather advisory and control information.

Consistent and comparable national-level data on safety and capacity indicators do not exist for this measure, and the RWMP needs to identify new sources and mechanisms for tracking this information. Where they exist, they are primarily collected at a regional or state level. Surveys conducted for this measure revealed a varying degree of use of relevant performance measures.

- Thirty-two percent (32%) of the survey respondents said they use a performance measure in which they measure Time to Wet/bare Pavement;
- Four percent (4%) of respondents indicated using a Percent of Time That Lanes Are Open During a Weather Event;
- Seven percent (7%) of respondents indicated using Pavement Friction Measurements for their performance measures;
- Eleven percent (11%) used Time to Pre-Event Travel Speeds after a Weather Event;
- Eighteen percent (18%) noted using Customer Satisfaction with Maintenance and Recover Time, based on Agency Surveys; and,
- Twenty-five percent (25%) also indicated using performance measures other than the given options.

One reply noted the current state performance measure is based solely on money, and when the state starts running low on money, the regions switch over to different chemicals. Another respondent noted their agency did not have statewide performance measures, but performance measures were left to the different regions. One other respondent noted tracking salt usage as a performance measure. [Note: This question permitted multiple responses]. For both winter and non-winter events a performance indicator is the frequency of use by agencies of road weather management controls to better regulate flow during weather events to promote safety.

The RWMP should encourage the tracking of key winter performance measures at a state-level to assess progress towards this measure, focusing especially on agencies/states that have implemented RMWP-supported products or services such as MDSS, MODSS or WRTM strategies.

Measure 2.3. Reduction in agency costs (i.e. labor, equipment, and materials) due to adoption of maintenance and operations decision-support systems for road weather management

The winter maintenance decision support systems for road weather management, including MDSS, are intended to provide state DOTs with more accurate and route-specific weather forecasts and road weather condition information to improve the timing of crew call-up and pre-treatment applications and guide decisions regarding which treatments and the timing and amount of those treatments with the objective of reducing staff and material requirements to most efficiently manage winter storm conditions and the impacts on pavement surfaces. MODSS systems offer comparable benefits at other times of the year for such activities as pavement striping, resurfacing, or roadside maintenance.

MDSS systems are currently offered by several vendors but they are in a very early stage of deployment and implementation by state DOTs. MODSS is only in a conceptual stage of development at this time. State DOTs that have adopted the MDSS include those that have not yet implemented them, or have only used them in a limited deployment (See Measure 1 under Goal 1). The latter include DOTs that are using their MDSS in some districts or locations and not others within their jurisdiction, or are using them along with other more traditional weather forecasting systems and therefore only partially basing their operational decisions on the MDSS.

Direct Effects:

- The RWMP has developed prototype modules for MDSS systems that have been incorporated into proprietary vendor systems and marketed to State DOTs. The RWMP has actively promoted the MDSS and developed a variety of marketing strategies designed to heighten awareness of the uses and benefits of these systems.

Indirect Effects:

- As part of WRTM, the RWMP is working with public agencies to review and self-evaluate their weather information needs and come up with integration strategies to suit their operational needs.
- Strategies aimed at reducing material and labor usage such as interaction with meteorologists, treatment practices such as anti-icing, pre-wetting continue to be identified and disseminated by RWMP.

Tracking this Measure:

National level statistics on expenditures for snow and ice removal are collected and available on an annual basis as part of the Highway Statistics publication series, a data compilation created and maintained by the USDOT FHWA Office of Highway Policy Information (OHPI). The data for state and local expenditures are reported by states and compiled. Figure 12 shows the national expenditures for snow and ice removal. The cost of snow and ice removal nationally is around $3 Billion annually.

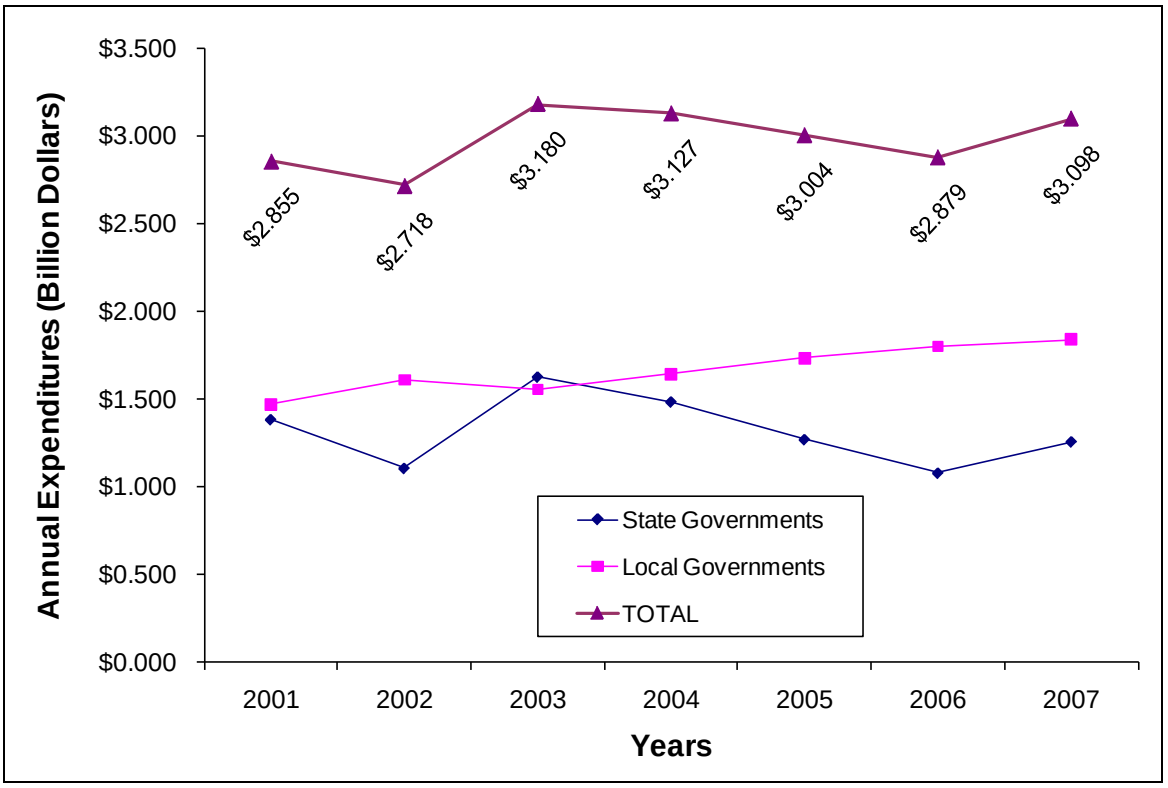

Figure 12. Annual Expenditures for Snow and Ice Removal (State and Local Governments)[20]

The annual totals are a weak indicator of RWMP performance. While long-term trends in the data above can be indicative of overall performance, seasonal and geographic variations in weather and road weather conditions, and local practices create significant variation in the data.

Of more importance from a RWMP performance standpoint is the evaluation of strategies that the RWMP directly or indirectly affects, and monitoring the benefits and levels of use. The RWMP is also sponsoring benefit-cost assessments of the MDSS to be able to demonstrate measurable cost savings as a way to further encourage states to support and fund deployment of the MDSS and MODSS.

As more states become aware of MDSS, either through direct involvement with the RWMP program and the federal prototype or through external actors such as the pooled fund and other private providers, the role of MDSS in providing quantifiable benefits in reducing labor and material costs for winter maintenance will become clearer. Table 6 lists the quantitative benefits currently reported due to the use of MDSS.

[20] Data from USDOT, FHWA, Office of Highway Policy Information, *Highway Statistics*, multiple years, Tables SF-4C and LGF-2.

Table 6. Evaluations of RWMP Strategies Aimed at Reducing Material and Labor Usage

Decrease in Costs due to use of Maintenance Decision-Support Systems				
Strategy	**Benefits ($/winter)**	**Location**	**Source**	**Overall Level of Use in United States**
Agency Savings per winter by using MDSS to maintain same conditions	$ 1,183,705	New Hampshire	Western Transportation Institute & Iteris, *Analysis of Maintenance Decision Support System (MDSS) Benefits & Costs*, Study SD2006-10 DRAFT Final Report, December 2008	30 agencies with some degree of use of MDSS, 5 with operational use
	$ 1,558,116	Minnesota		
	$ 1,717,583	Colorado		
Agency Savings by using MDSS to make tactical shift deployment decisions	$74,000 in shift savings (2008)	City and County of Denver	Battelle, *Evaluation of an MDSS implementation in the City and County of Denver*, forthcoming	
Agency Savings	$12,108,910 (228,470 tons) in salt usage (41% reduction) $1,359,951 (58,274 hours) in overtime Compensation (26% reduction)	Indiana	Indiana Department of Transportation (INDOT) *Maintenance Decision Support System (MDSS): Statewide Implementation,* Final Report for FY09, Draft, May 2009	

In addition to MDSS, the RWMP has been promoting other best practices to reduce material and labor costs. Treatment actions such as anti-icing and pre-wetting have demonstrated significant material and costs savings.[21] Overall, while national level statistics are scarce at this time, evaluations of MDSS deployments as well as of other treatment strategies show significant benefit and progress towards reducing material and labor costs. The RWMP should continue to track and compile evaluation results as a means of measuring performance of these decision support systems.

Measure 2.4 Reduction in user costs (i.e. delay, crashes, vehicle operating costs, emissions, salt damage) due to improved road weather advisory, control and treatment strategies

Each year 22 percent of injury and fatal crashes can be attributed to adverse weather and its effect on visibility and road surfaces (snow, rain, etc.).[22] Weather is a contributing factor in many ways to crashes. Table 7 shows the different critical reasons for a pre-crash event. The data are for crashes in which the critical cause was attributed was roadway or atmospheric conditions. Among such crashes, about 75 percent were related to roadway conditions, such as slick roads,

[21] USDOT, RITA (2008), *ITS Benefits, Costs, Deployment, and Lessons Learned.*
[22] Lynette C. Goodwin. *Analysis of Weather-Related Crashes on U.S. Highways*, 2002.

view obstruction, signs and signals, road design, etc. This consisted of about 50 percent crashes in which the critical reason was slick roads, 11.6 percent related to view obstructions, and 2.7 percent attributed to signs and signals. In addition, in 8.4 percent of the environment-related crashes, the critical reason was weather condition, the most frequent (4.4%) being fog/rain/snow. Glare accounted for about 16 percent of the environment-related crashes.

Table 7. Weather-Related Critical Reasons for Crashes[23]

Causal Factors	Number of Crashes		Weighted Percentage
	Un-Weighted	Weighted	
Roadway conditions			
Slick roads	58	26,350	49.6%
View obstructions	19	6,107	11.6%
Signs/signals	5	1,452	2.7%
Road design	3	745	1.4%
Other highway-related conditions	9	5,190	9.8%
Atmospheric conditions			
Fog/rain/snow	11	2,338	4.4%
Other weather	6	2,147	4.0%
Glare	24	8,709	16.4%

Figure 13 shows the national trends for crash rates due to weather conditions per thousand overall population and licensed drivers. There may be a number of causes for the observed variations in rates since 2003 in addition to contributions by the information and systems that have been provided by the RWMP over this period.

[23] Data Source: National Motor Vehicle Crash Causation Survey (NMVCCS) (July 3 2005 to December 31, 2007), NHTSA, compiled as of April 30, 2008. Estimates may not add up to totals for independent rounding.

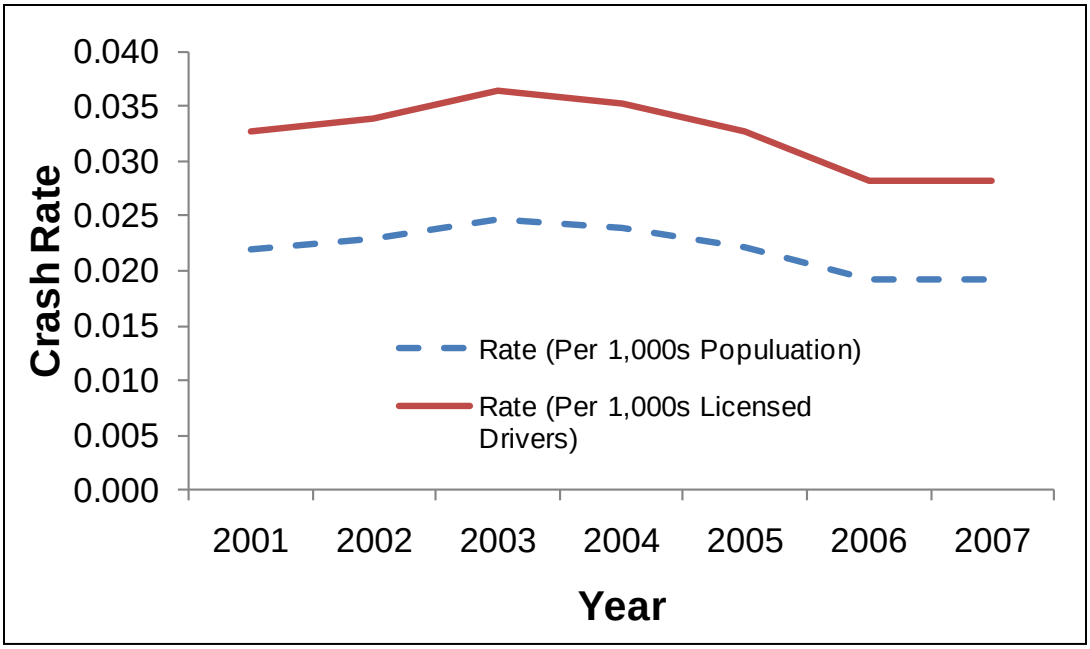

Figure 13. Crashes Attributed to Weather per 1,000s of Population and Licensed Drivers

Similarly, data compiled by the RWMP indicate that average speeds on roadways are reduced between 3% and 40% by weather that ranges from light rain to heavy snow[24]. Empirical studies on traffic flow during weather show that weather events impact free flow speed, speed at capacity and capacity at varying intensities. Negative impacts for free flow speed ranged from a minimum of 2% (during light rain) to a maximum of 19% (during snow). Capacity reductions ranged from 10% to 20%.[25]

A direct measurement of weather-related delays is difficult to obtain at a national level. The data are sparse regarding state or local level delays. A potential model was developed in 2002 by the Oak Ridge National Laboratory[26] to identify temporary reductions in capacity using national level data. The study estimated the capacity losses and delays due to fog, snow and ice events. The methodology allows for a national summary of capacity and delays due to weather events. For example, the study reported in 1999 fog, snow, and icy conditions reduced capacity on freeways and principal arterials by approximately 24 billion vehicles. This resulted in an estimated 543.9 million vehicle-hours of delay. Most of this estimated delay (90 percent) was due to snow in urban areas. Icy conditions accounted for 7 percent of the estimated delay from these weather conditions, and fog accounted for about 3 percent. The study broke down the delays for the following functional classes of roadways:

[24] USDOT, FHWA, Road Weather Management Program. How Do Weather Events Impact Roads? [Website]. Accessed on August 27, 2009 from http://ops.fhwa.dot.gov/Weather/q1_roadimpact.htm.
[25] Hranac, R., Sterzin, E., Krechmer, D., Rakha, H., and Farzaneh, M. Empirical Studies on Traffic Flow in Inclement Weather, Report No. FHWA-HOP-07-073, 2006.
[26] Chin S.M., Franzese O., Greene D.L., Hwang H.L., Oak Ridge National Labs, Gibson R.C., University of Tennessee, Temporary Losses of Highway Capacity and Impacts on Performance, May 2002.

- Urban freeways
- Urban principal arterials
- Rural freeways
- Rural principal arterials

While RWMP actions have resulted in widespread dissemination of best practices in advisory, control and treatment strategies and have resulted in successful deployments nationally, the contribution of specific strategies on national crash rates is hard to determine and attribute to the RWMP program. Consequently, indicators in Measure 4 focuses on reductions in user costs associated with, for example, delays or crashes, due to specific road weather strategies that have been supported by the RWMP. Two indicators support this measure.

Indicator 1: Reduction in crashes attributed to weather conditions due to RWMP supported practices

Direct Effects:

- While all of the RMWP R&D programs have safety as an important component, the WRTM program strives to directly reduce the risk experienced by travelers driving in bad weather. Currently, agencies implement a wide variety of WRTM strategies in many different ways. The RWMP is working on developing, improving and evaluating WRTM strategies to provide agencies with a well-tested and practical toolbox for advisory, control and treatment operations.

Indirect Effects:

- Adoption of decision-support tools like MDSS can improve agency response and treatment to weather conditions, thereby reducing the safety risks during inclement weather conditions. Also, the RWMP's participation in the DOT IntelliDrive Program will directly address safety issues.
- Specifically, the best practice database maintained by the RMWP provides states with techniques to reduce user costs through advisory systems that address fog, high wind, floods, and adverse road conditions; treatment strategies such as pavement de-icing systems and MDSS, and control strategies.

Tracking this Indicator:

The primary source of data for tracking this indicator comes from the ITS Benefit-Cost Database maintained by the USDOT ITS Joint Program Office (ITS-JPO). The data in the Table 8 are a compilation of the benefits reported in various deployments around the country over an extended period of time. These data show estimated reductions in crashes in 2007 experienced by states that have deployed WRTM strategies. These data suggest that the RWMP, by encouraging the use of these systems and strategies, can have a significant beneficial impact on crash reduction and, hence, enhanced roadway safety.

Indicator 2: Reduction in delays due to adverse weather conditions due to RWMP supported practices

Direct Effects:

- The WRTM program strives to directly reduce the delays experienced by travelers driving in bad weather.

Indirect Effects:

- Similar to the previous indicator, proven and tested techniques to reduce user costs have been compiled and disseminated to agencies.

Table 8. Estimated Crash Reduction Due to RWMP Best Practices

Best Practices	Percentage Reduction in Crashes*	Level of Use by States (2007)*
Fog Warning System	70-100%	~12
Road Weather Information System	3-17%	33
Variable Speed Limits	8-25%	5
Anti-icing Strategies	7-83%	nd
Wet Pavement Detection	39%	nd
Automated Anti-icing on Bridges	25-100%	20
Conditions on DMS	2.80%	29
Conditions on HAR	nd	18
Conditions on 511	nd	23
Water Level Monitoring	nd	15

* nd = No Data

Tracking this Indicator:

Similar to the previous indicator, the data for this measure is a compilation of benefits reported in various evaluations in the ITS Benefit-Cost Database. As is the case with crash reduction, RWMP best practices implemented by state DOTs have served to reduce speed, capacity and delay impacts associated with adverse weather. Table 9 shows the impacts of several of these strategies on capacities and delays.

Table 9. Impacts on Speed, Capacity and Delays due to RWMP Best Practices

Strategies	Capacity and Delay, Impacts (examples from selected states)*	Level of Use by States (2007)
Low Visibility Warning Systems	More uniform traffic flow Reduced speed variability by 22% Speeds increased 11%	~12
Weather-related Signage on DMS	nd	29
Weather Information on 511	nd	23
Highway Advisory Radio	1/3 of CVOs reported considering changing routes based on information	18
Variable Speed Limits/Speed Management	Reduced average speed by 13%	5
Weather-related Signal Timing	Reduced vehicle delay 8% Reduced vehicle stops over 5%	4
Weather and/or Road Condition Information on Websites	94% travelers - better prepared to travel 56% travelers - helped avoid delays	37

* nd = No Data

V. Goal 3: Promote Technology Transfer of Effective Road Weather Scientific and Technological Advances

The RWMP has involved the transportation and meteorological communities using a combination of training, outreach, peer exchanges, conferences and collaborative research with universities, private entities, and state and local agencies to foster an engaged and active stakeholder group supporting road weather research and development. There are four measures under Goal 3, two of which are supported by three indicators each. Goal 3 addresses the RWMP's marketing, outreach and efforts to engage state agencies in the RWMP's programs and technologies.

The four measures under Goal 3 seek to quantify the extent to which the RWMP has been able to engage a wide range of stakeholders and potential users of road weather technologies, communicate the benefits, promote usage, and successfully transfer operational tools and systems to states and agencies across the country. State DOTs have indicated the value they attach to these activities through their participation in outreach activities sponsored by the RWMP and by actively seeking weather-related information and adopting new weather technologies to support their core operations. These state DOTs traditionally interpreted their jobs in terms of construction, operation and management of transportation infrastructure. Now they are increasingly supportive of the underlying tenet of Intelligent Transportation Systems (ITS) that seeks to encourage a focus on enhancing the safety, efficiency, and productivity of existing systems. In this context, the RWMP is working to expand the vision of transportation system operators to more proactively integrate road weather into their daily activities consistent with the ITS philosophy.

Although indicated as the third goal of the RWM program, this goal reflects the first step in the process of raising awareness of the benefits of adopting RWM technologies and systems. Effective outreach and technology transfer enables agencies to address the significant effects of weather and road conditions affected by weather on the safety and satisfaction of the traveling public. The RWMP has taken steps in this direction to provide training and direction, and achieved measurable progress in terms of agency awareness, involvement, and adoption of such systems as the *Clarus* Initiative and MDSS. Much more progress along these lines can be expected in the future as these systems mature.

The four measures under this goal address direct effects of the RWMP in bringing together the transportation community towards increased awareness and use of road weather information and products. The primary source for tracking the data to quantify the four measures is the RWMP itself. Records of stakeholder involvement and participation at meetings, webinars, training courses and other outreach forums serve as primary sources of data for this measure.

Measure 3.1. Number of agencies/individuals visited or contacted through technology transfer, training and outreach efforts.

Measure 3.1 examines how many state agencies, particularly state DOTs and the key individuals working in those DOTs, have been engaged in any of the RWMP's technology transfer, training or outreach activities. The RWMP has sponsored meetings, workshops, conferences and prepared materials related to several of their core projects, including the *Clarus* Initiative and MDSS. In addition, they have hosted, sponsored and promoted a variety of training programs in support of these two projects and a number of their other projects and activities. There are three indicators that seek to measure progress in these areas, and specifically provide evidence in support of this measure, as they contribute to achievement of Goal 3.

1. Number of transportation agencies participating in *Clarus* initiative activities.
2. Number of transportation agencies participating in MDSS stakeholder meetings.
3. Number of participants in RWMP hosted, sponsored or promoted training.

Involvement in the *Clarus* Initiative has increased significantly between 2004 and 2008, with participation in the annual stakeholder meetings having increased threefold over this period (Figure 14). During the period May to July, 2009, 30 state agency representatives were contacted by telephone and interviewed in order to collect additional data on the extent of awareness, acceptance and use of RWMP products and involvement in RWMP-promoted activities. The results show extensive involvement in *Clarus* Initiative activities, with 22 of 30 respondents (73%) saying they or their agency has been involved with that program (Figure 15).

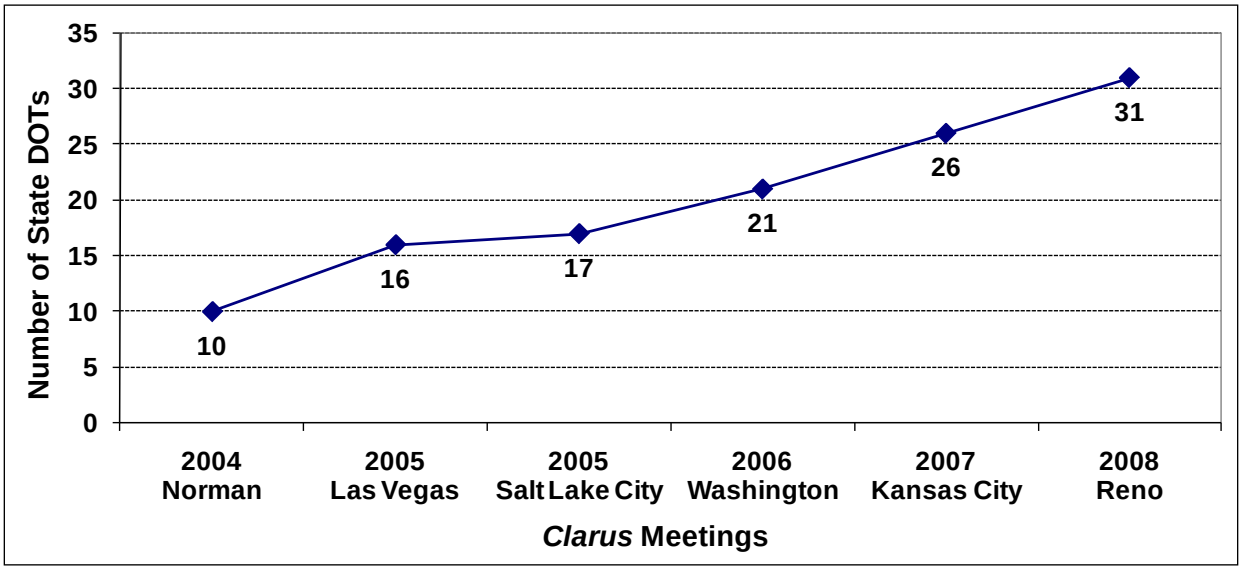

Figure 14. Participation in *Clarus* Stakeholder Meetings: 2004 – 2008

Since the year 2000, 41 state DOTs have participated in one or more MDSS stakeholder meetings, and the level of participation in any one year has remained relatively stable over this period (Figure 16). Results from the agency interviews indicate 17 of 30 agencies (57%) are actively involved with the MDSS program (Figure 15), and 13 (43%) said they are involved in both the *Clarus* Initiative (including providing data to the *Clarus* System) and MDSS programs.

Of those respondents reporting no involvement in either of these two programs, several indicated they were considering future involvement in either the *Clarus* Initiative or MDSS. The response patterns suggest there are greater awareness, engagement and acceptance in the *Clarus* Initiative and MDSS programs than in the other RWMP projects. While it is still early in the deployment of each of these programs, as noted in Measure 2.1, a high percent of the respondents (88%) reported deriving either "substantial benefits" (38%) or "moderate benefits" (50%) from their involvement in *Clarus* and MDSS. In their supporting comments, some respondents noted they specifically appreciate having access to ESS data from neighboring states, quality controlled data, and environmental benefits along with financial benefits.

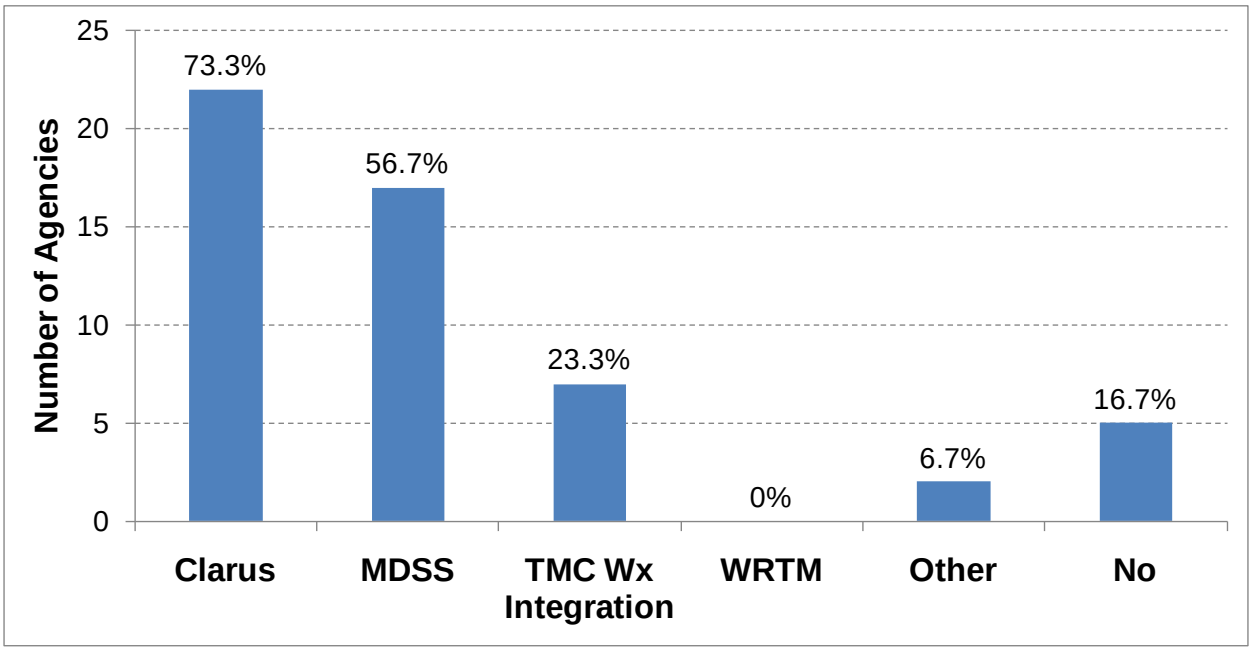

Figure 15. Agency Involvement in the RWMP's R&D Projects

While there is agency involvement in the WRTM activities, none of the agency respondents interviewed was aware that their agency was involved. Although the TMC weather integration project is currently focused on only selected TMCs across the country, 23% of the interviewees said their agency was involved. This was asked as a separate question in the interviews, even though the TMC integration project is a part of the larger WRTM program.

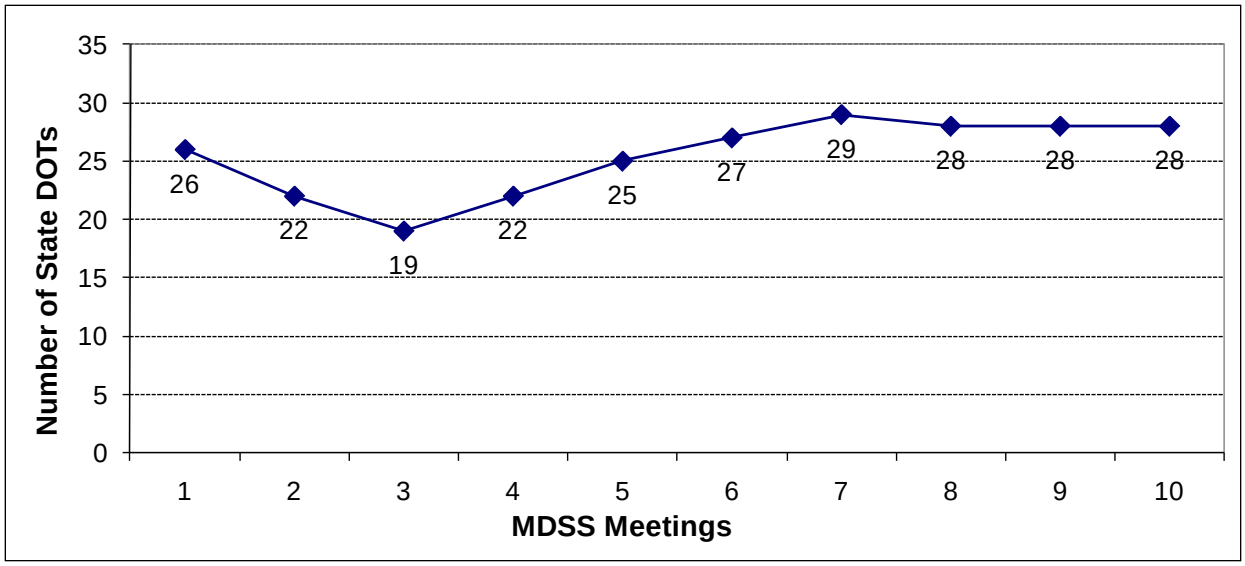

Figure 16. Participation in MDSS Stakeholder Meetings: 2000 – 2008

The third indicator covers participation in RWMP-sponsored or promoted training. Four courses have been presented on "Principles and Fundamentals for Road Weather Management" that have drawn a total of 113 participants to four on-site locations (Table 10). Two additional blended courses on this topic drew 38 participants in 2008. An Institute of Transportation Engineers (ITE) course on the same subject in 2008 had 40 participants. Also, the RWMP has sponsored the "MDSS Road Show" that has been conducted 28 times between 2006 and 2008 across the country. Through the *Clarus* Initiative and MDSS meetings and sponsored training activities, the RWMP has reached a wide audience of key stakeholders.

Further support for progress on Measure 3.1 is provided by the transportation agency interviews, in which 22 out of 28 (79%) said they or a member of their agency had visited the FHWA RWMP web site. Of those who visited the web site, 12 said they downloaded either research reports, guidance documents, or other tools and information, and 10 said they either didn't download anything or they didn't know or weren't sure whether they or others had downloaded anything from that site. In addition, 20 of 28 respondents (71%) said they have either attended or presented in the FHWA National Transportation Operations Coalition (NTOC) webcasts, which is a forum that the RWMP uses to communicate with its national constituency. Figure 17 shows the number and percent of respondents who visited the web site and reported they downloaded one or more documents from the RWMP web site, or did not or were not sure. Many said they downloaded more than one of these items.

Table 10. Attendance at Road Weather Management Training Events

Training Activities and Sponsorship	Number of Events	Number of Attendees	Details of Event
NIH Onsite Course: Principles and Fundamentals of Road Weather Management	4	35	Rapid City, SD
		17	Huron, SD
		32	Bismarck, ND
		29	Manchester, NH
NHI Blended Course: Principles and Fundamentals of RW Management (CITE Maryland)	2	29	Spring 2008
		9	Fall 2008
ITE Course - Fundamentals of Road Weather Management	1	40	Fall 2008
RWMP MDSS Road Show	14	480	2006
	11	226	2007
	3*	219	Omaha, NE (May 2008) King of Prussia, PA (Aug. 2008) Boise, ID (Sept. 2008)

* In 2008, the Road Show was held as a regional event, with each location hosting participants from neighboring states and the private sector. Thus, 2008 event figures are not directly comparable with prior years.

The use of road weather information and decision support systems is well supported by both available program participation data and by the interviews with the state agencies that the RWMP has sought to support and engage. What is more difficult to capture with available data is a clear understanding of *how* these agencies are using this information and these support systems in their day-to-day decision making. Thus, the extensiveness of use throughout a DOT's jurisdiction or the role of the information in supporting advisory, control and treatment decisions is more complex and generally beyond the reach of the available data. The RWMP can consider establishing state DOT record keeping guidelines for routinely tracking a simplified set of data items to help fill the current gaps in our ability to fully implement Measure 3.1. Periodic interviews with a sample of state agency representatives, similar to the interviews conducted for this study but with a refined and expanded set of questions, could be implemented annually to help understand the nuances associated with the RWMP's efforts to increase the use of road weather information and technologies.

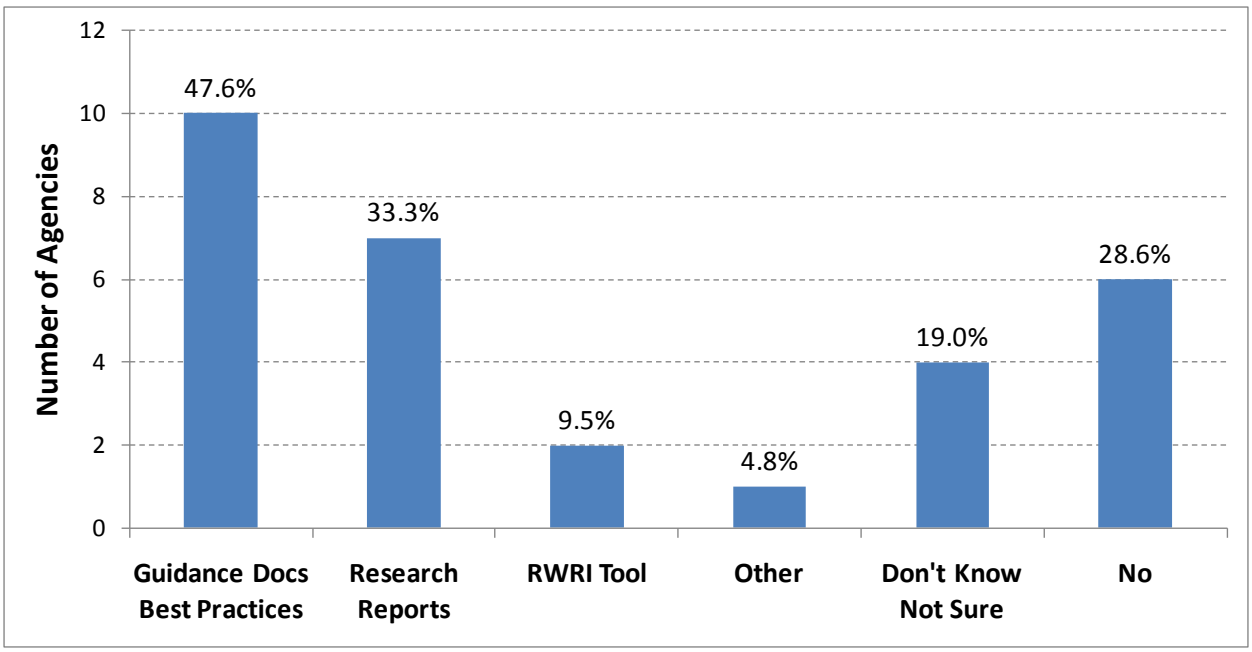

Figure 17. Products Downloaded by Agencies from the RWMP Website

Measure 3.2. Rate of adoption of RWM technologies (e.g., decision-support systems) by agencies that participated in workshop or training activities.

Measure 3.2 addresses the extent to which agencies that have participated in workshops or training have adopted RWMP technologies. Unfortunately, no data have been collected to track participants in these activities and find out whether their agencies have adopted RWMP technologies, either as a result of their participation in those activities, or otherwise related to their participation. Data have already been presented under Goal 1 that show the level of agency adoption of such key technologies as the *Clarus* system and MDSS. Data are also available on the number of agencies that are contributing their ESS data to the *Clarus* system. The RWMP sponsors stakeholder workshops for both the *Clarus* Initiative and MDSS programs, and attendees at those events represent agencies that have adopted the technologies, as well as other agencies that are considering adoption in the future and are seeking more information. While there is apparently a strong relationship between involvement in these technology programs and participation in workshops and training sponsored by the RWMP, the data are not yet available to measure this relationship. In order to better understand the cause and effect relationship between participation in workshops and training, and adoption of these RWMP technologies, the RWMP will need to collect data in the future from participants in these events and ask them whether their agencies have adopted the technologies and why they decided to do so.

In 2006 there were three agencies that contributed ESS data to the *Clarus* system, and by 2008, 33 agencies had contributed data from 1,700 ESS (Figure 18). Agencies include both state and local agencies. As has been noted already, the *Clarus* Initiative is just now getting off the

ground, and more agencies are expected to contribute significantly more data to the*Clarus* system in the future. The second indicator of RWMP technology adoption is the extent of public and private sector use of quality-checked *Clarus* system data (Table 11). This indicator will become more useful as the *Clarus* system evolves, but in the early phases of this initiative, at least five private sector entities are active users of *Clarus* system data. States are starting to acquire *Clarus* system data, and applications are being developed as part of Phase III of the *Clarus* Initiative regional demonstrations that are expected to be deployed in about 8 states by 2010. The third indicator for Measure 3.2 is the number of states adopting MDSS technologies and methods. This indicator also supports Goal 1, Measure 1, and the data were reported under the Goal 1 discussion.

Table 11. Public and Private Sector Use of Quality-checked *Clarus* System Data

Number of private sector providers that use ESS data that have been quality-checked by *Clarus*.	**5**	XM Weather, Quixote, Meridian Environmental Technology, Baron, DTN
Number of states and/or public agencies with applications based on the *Clarus* System.	**0**	While there are states now acquiring *Clarus* System data, there are no data to suggest that any applications presently exist based on the *Clarus* System. Applications are being developed as part of Phase III of the *Clarus* demonstrations that will be deployed in about 8 states by 2010.

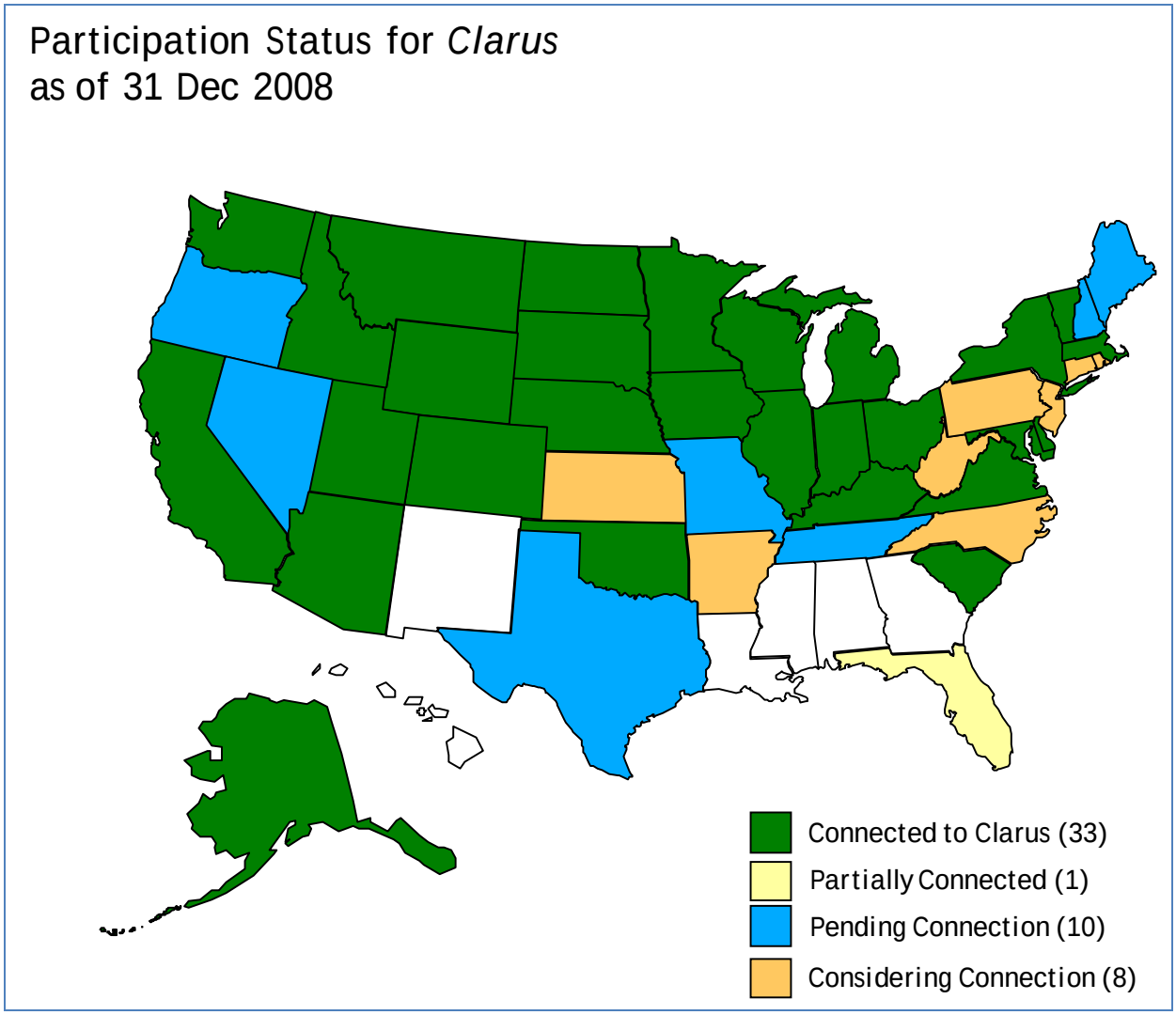

Figure 18. Agency Participation in *Clarus* System: December 31, 2008

Measure 3.3. Number of RWM technology development, testing and deployment activities initiated through public or private sector based on identified operational needs.

Measure 3 addresses the number of RWMP development, testing and deployment activities of both the public and private sectors. Between 2001 and 2008 approximately 90 projects have been initiated through Federal, state and university sponsorship. These include 46 projects conducted with the states, 40 university projects, and 4 Federal projects. Attention at the Federal level channeled through the RWMP has helped move these projects forward. The role of the RWMP has primarily been a collaborative one, and the agencies and universities engage in and leading these activities are chiefly responsible for the successes produced by these projects.

Measure 3.4. Number of road weather technologies developed through public-private and/or public-public partnerships reaching operational deployment.

Measure 4 addresses the number of road weather technologies developed through partnerships that have reached operational deployment. Table 12 lists eight such technologies that are in various stages of operations across the country.

Table 12. Operational Road Weather Technologies by Partnership Type

Technologies	Partnership Type
Condition Acquisition and Reporting System (CARS)	Public-Private
Meridian Environmental Technology-MnDOT Weather Response Index	Public-Private
MDSS (Pooled Fund / Meridian Environmental Technology)	Public-Private
WeatherShare (WTI-CalTrans)	Public-Public
#SAFE (UND - NDDOT/SDDOT)	Public-Public
Avalanche advisories (WTI - MtDOT)	Public-Public
Roadway Environment Blowing Snow Modeling (UND-PFS MDSS)	Public-Public
Federal Prototype MDSS (NCAR-FHWA)	Public-Public

Each of the technologies shown in Table 12 is being used by states and agencies, and each has been supported in some manner by the RWMP which has tended for the most part to play a collaborative or consultative role in partnership with each of these entities, including in a number of these providing financial support for technology development.

VI. Summary

The key findings under each of the three SAFETEA-LU goal areas are summarized in this Chapter. The measures under Goal 1 primarily seek to address changes over time in the use of road weather information products and services. Deployment statistics data from 2004 to 2007 show increases in usage of road weather information in all aspects of operations.

- The number of states disseminating weather information to travelers has increased across various dissemination mechanisms from 2004 to 2007. In addition, the types of weather information disseminated have also substantially increased.
- A variety of control strategies were reported by states in 2007, ranging from 30 states reporting the use of technologies to manage diversions and closures during inclement weather to 5 states reporting the use of variable speed control during weather events.
- Since becoming a mature technology in 2005, MDSS has been utilized and tested by 30 agencies in 2008 in some manner with 5 agencies reporting operational use of MDSS.
- Subscription to public and private road weather products and services has increased over the past three years.

The RWMP has had many direct and indirect effects on the increase in use over the past three years by promoting the use of weather information in transportation operations around the country through a variety of activities including providing tools, conducting field tests and demonstrations, collaborating with private and public agencies for improved road weather information services, promoting best practices for weather information integration, weather-responsive traffic management, and development of the *Clarus* system and MDSS.

While increase in use and access has been clearly demonstrated, the quality and nature of use among agencies vary greatly. In other words, future performance measurement, in addition to tracking usage, needs to monitor quality of use when possible. The RWMP study on "*Baselining Current Road Weather Information*" can provide valuable information in this regard in addition to specific deployment evaluations.

The four measures under Goal 2 seek to quantify the extent to which agencies are engaging in activities that will enhance the safety, capacity, and economic advantages of addressing the impacts of adverse weather conditions on roads and travelers, and do that while also minimizing impacts to the environment. National level trends reflect positively on RWMP performance. Although many of the best practices and new technologies being promoted by the RWMP have only recently become available, state transportation agencies are eagerly adopting them. Best practices have existed prior to the RMWP, and the RWMP has sought to promote and catalyze increased adoption and use of these techniques. Clear results are difficult to quantify in this early and selective nature of the deployments but the evidence to date suggests significant use and benefits. At the local levels of deployment, RWMP tools, products and services and the best practices that the RWMP supports have resulted in wide-ranging benefits in terms of safety, mobility, efficiency, productivity and customer satisfaction. Monitoring levels of use coupled

with project evaluations clearly indicate that RWMP programs are having real benefits under this Goal 2.

The four measures under Goal 3 seek to quantify the extent to which the RWMP has been able to engage a wide range of stakeholders and potential users of road weather technologies, communicate the benefits, promote usage, and successfully transfer operational tools and systems to states and agencies across the country.

- Awareness and participation in the RWMP is very high among the states, and they report significant benefits from participation in the program.
- Participation in RWMP initiatives like *Clarus* and MDSS has continued to increase along with usage over the last four years.
- In-person and web-based training activities, road shows, and informational webinars sponsored by the RWMP are widely attended and appreciated.
- Close to 90 projects have been initiated in the area of Road Weather Management by private, public and academic groups that are involved with the RWMP.

RWMP performance findings are summarized in Tables 13-15, and the available data have been collected either in direct support of a measure or indirectly through one or more indicators that are linked to the measure. The data vary in their ability to support the measure, and some of the indicators only offer weak linkage to their measure. These issues are discussed further in the report and recommendations made regarding future adjustments to the measures and indicators, as well as the need to identify new sources of data that can offer stronger support for the measures. Currently, the available data sources include the ITS-JPO Deployment Statistics and Benefit-Cost databases, RWMP program records, and transportation agency surveys and interviews conducted as part of this project.

As has been pointed out in this report, the RWMP plays a variety of roles in its efforts to achieve the goals set for it under SAFETEA-LU, and these include initiating and implementing programs and projects that are designed to advance the frontiers of road weather research and development, providing training, engaging in partnerships and collaborative efforts, heightening awareness of the value of road weather information and its potential uses, and always seeking to encourage others to become more engaged in the application of road weather information and tools in support of advisory, control and treatment strategies in making our transportation systems safer and enhancing mobility. Both prior to the establishment of the RWMP, and since initiation of the range of activities and services described in this report, Federal, state and local agencies and the private sector have played, and will continue to play, a very significant role in the achievement of this program's goals. While this report has sought to highlight the performance of the RWMP as illustrated by the findings shown in Tables 13-15, the attainment of the SAFETEA-LU goals is ultimately a widely collaborative effort in which the RWMP plays a leadership role.

Table 13. Summarized Results for Goal 1 of Measures of RWMP Performance

Performance Measure	Indicators and Data that Support the Measure
Goal 1: Maximize use of available road weather information and technologies.	
1.1 Number or percentage of transportation agencies that use road weather information and decision support systems (based on current or forecast information) for making advisory, control and treatment decisions.	• The number of states providing travelers with weather information, using DMS, HAR, 511 or Web, increased on average 46% between 2004 and 2007. • States increased their dissemination of six specific types of weather information between 2004 and 2007 by an average of 49%. For example, 22 states reported providing route-specific weather forecasts in 2007, an increase of 69% over 2004. • In 2007, 46 states reported using atmospheric data and 45 states using pavement data for their operations, 30 states used ITS technologies to implement weather-related control strategies to manage road diversions or closures, and 15 states were using such strategies to implement temporary road restrictions. • MDSS usage has grown rapidly since 2004, and by 2008, 30 transportation agencies reported some use of MDSS, and five agencies reported operational use of MDSS to support winter maintenance operations. • Between 2004 and 2007 the number of state DOTs using weather information increased an average of 31%, with 45 state DOTs using NWS information, an increase of 29% over 2004 usage.
1.2 Number or percentage of travelers who use road weather information for making travel decisions (both pre-trip and en-route).	• In 2008, 33 states had 41 operating 511 systems, and 25 of those offered some type of road weather information. • On average, an estimated 12% of calls to 511 have accessed weather information
1.3 Number of environmental sensor stations (ESS) deployed and used by transportation agencies to support decision-making (normalized by total area or length of road network).	• Between 2006 and 2008 the number of agencies contributing their ESS data to the *Clarus* System increased from 3 to 33, and these 33 agencies had 1,700 ESS reporting data to the *Clarus* System, which is about 68% of the national ESS deployed. • Between 2004 and 2007 the number of agencies providing ESS data for agency use increased from 26 to 30 (15%), and for public use from 38 to 45 (18%).

Table 14. Summarized Results for Goal 2 of Measures of RWMP Performance

Performance Measure	Indicators and Data that Support the Measure
Goal 2: Expand road weather research and development efforts to enhance roadway safety, capacity and efficiency while minimizing environmental impacts.	
2.1 Number of agencies participating in and benefiting from road weather R&D projects.	• Of 24 state agency respondents to interviews in 2009, 21 (88%) said they experienced moderate or substantial benefits (50% moderate and 38% substantial), and 20 of these respondents said they were involved in more than one RWMP activity.
2.2 Percentage of time roadway meets safety and capacity level of service (LOS) standards (i.e. V/C ratio, etc.) during and after weather events (normalized by the frequency/intensity of winter events).	• National level statistics do not exist yet to directly address this measure but interviews revealed that agencies are beginning to use performance measures to track safety and capacity level of service. • 32% of agency respondents interviewed in 2009 said they measure "time to wet/bare pavement." • 4% measure "percent of time that lanes are open during a weather event." • 7% measure "pavement friction measurements." • 11% measure "time to pre-event travel speeds after a weather event." • 18% measure "customer satisfaction with maintenance and recover time." • 25% use other performance indicators.
2.3 Reduction in agency costs (i.e. labor, equipment, and materials) due to adoption of maintenance and operations decision-support systems for road weather management.	• Between 2001 and 2007, nationwide costs for snow and ice removal ranged from $2.7 billion to $3.2 billion annually. • Selected evaluations of MDSS usage show savings by three states that range from $1.2 million to $1.7 million per winter. • A city maintenance unit saved $74,000 in shift labor costs in the 2008 winter. • Another state reported saving $12.1 million in salt usage and $1.4 million in overtime compensation from previous years. These correspond to a 41% reduction in salt usage and a 26% reduction in overtime compensation.
2.4 Reduction in user costs (i.e. delay, crashes, vehicle operating costs, emissions, salt damage) due to improved road weather advisory, control and treatment strategies.	• The RWMP encourages use of best practice technologies that reduce user costs due to weather and save lives. While these best practices may not have been developed by the RWMP, they are increasingly being used by transportation agencies and promoted by the RWMP as part of their program. • Fog warning systems have reduced crashes by 70 to 100%; RWIS use by up to 17%; anti-icing strategies by up to 83%; wet pavement detection by 39%; and conditions reported on DMS by 2.8%. • Low visibility warning systems reduced speed variability by 22% and increased speeds by 11%; HAR messages helped CVOs make better route choices; variable speed limits reduced average speed by 13%; weather-related signal timing reduced vehicle delay 8% and vehicle stops by more than 5%; and weather and road condition information on websites lead to increased traveler satisfaction (94% reported being better prepared and 56% reported it helped avoid delays due to weather).

Table 15. Summarized Results for Goal 3 of Measures of RWMP Performance

Performance Measure	Indicators and Data that Support the Measure
Goal 3: Promote technology transfer of effective road weather scientific and technological advances.	
3.1 Number of agencies/individuals visited or contacted through technology transfer, training and outreach efforts.	• Between 2004 and 2008, state DOT participation in annual *Clarus* stakeholder meetings promoted by the RWMP increased from 10 to 31 (68%). • Of 30 state agency representatives interviewed in 2009, 22 (73%) reported their agency was involved in the *Clarus* Initiative. • Between 2000 and 2008, 41 state DOTs have participated in one or more annual MDSS stakeholder meetings, and the participation level has remained stable. • Agency interviews in 2009 indicate 17 of 30 agencies (57%) are involved with MDSS and 13 of 30 agencies (43%) with both the *Clarus* Initiative and MDSS. • Agency interviewees reported deriving either "substantial benefits" (36%) or "moderate benefits" (48%) from their involvement in *Clarus* and MDSS, even though these are new programs. • The RWMP sponsored 6 road weather management training courses over the past several years that drew 151 attendees. An ITE course on *Fundamentals of Road Weather Management* had 40 participants in 2008, and the RWMP sponsored MDSS Road Show has been conducted 28 times between 2006 and 2008 with 925 participants across the country. • 22 out of 28 agency interviewees (79%) reported visiting the RWMP website, and 12 said they downloaded materials. 20 of 28 respondents (71%) said they participated in one of the NTOC webcasts.
3.2 Rate of adoption of RWM technologies (e.g., decision-support systems) by agencies that participated in workshop or training activities.	• Between 2006 and 2008, the number of state and local agencies contributing ESS data to the *Clarus* System increased from 3 to 33. • In the early deployment of the *Clarus* Initiative, 5 private sector entities are active users of *Clarus* System quality-checked data. • As noted under Measure 1.1, by 2008, 30 states and local agencies reported some use of MDSS, and five agencies reported operational use of MDSS to support winter maintenance operations.
3.3 Number of RWM technology development, testing and deployment activities initiated through public or private sector based on identified operational needs.	• Between 2001 and 2008 approximately 90 projects have been initiated through federal, state and university sponsorship with RWMP input and support.
3.4 Number of road weather technologies developed through public-private and/or public-public partnerships reaching operational deployment.	• Eight public-private and public-public partnerships supported by the RWMP are in various stages of operations across the country.

VII. Continuing Process of Performance Assessment

As the framework described in Goal 1, 2 and 3 show, multiple measures and indicators, supported by a variety of relevant data sources are required to look at all available evidence in assessing the RWMP's performance to date. This is only the first step for the application of performance metrics in the RWMP. Applying these measures consistently over time will give a more complete picture of performance, particularly as the data improve and are collected more systematically with the purpose of supporting the metrics.

The framework takes advantage of many of the existing sources of data collection, minimizing the data collection costs to the program. Several sources of data are particularly important to the program

- *ITS Deployment Statistics.* To continue monitoring the performance of the RWMP, it is critical that the program work with the ITS-JPO to use the ITS Deployment Survey as a primary data source for quantifying the level of use and adoption of RWMP supported programs, services and activities. Having relevant questions included in the continuing national surveys can provide the RWMP with a majority of the data for the indicators identified particularly on the level of use of RWMP products, services and supported strategies.
- *Project Evaluations and Benefits Database.* Of more importance from an RWMP performance standpoint is evaluation of strategies that the RWMP directly or indirectly affects and monitoring the benefits and the levels of use. Many of the RWM programs are at research stages or being deployed by a few sites nationwide and are being evaluated. These evaluations need to be compiled as part of the performance measurement. The ITS-Benefits Database maintained by the ITS-JPO is a useful repository for compiling evaluation results.
- *Data from the RWMP*. These program data are the best source for many of the indicators identified. This is especially true for the output type measures in Goals 1 and 3 regarding participation of state agencies in RWMP activities. The RWMP should continue to collect information on participation but also have an evaluation component as part of their outreach activities focusing on quality and benefits that the stakeholders are deriving from participation in RWMP activities.
- *Focused RWMP sponsored surveys/interviews of state DOTs*. Such survey can capture the awareness, acceptance and use of specific RWMP products and activities at a level of detail not possible by the more general ITS Deployment Statistics surveys. By creatively framing questions, the survey can be used to obtain a detailed assessment of specific programs. An example of such a survey is the *Baseline Weather Information Surveys* carried out by the RWMP that focused on the quality attributes of weather information. The baselining work will continue every two years and will provide information relating changes in the quality characteristics of ESS to road weather, including usage by transportation agencies. The biggest challenges with the online survey are lack of adequate responses, and the identification of the survey participants. The lack of adequate responses is more critical especially since several measures require national summaries.

Ideally, performance measurement will be carried out annually or bi-annually, focusing on improvements that can be assessed against this baseline. By maintaining consistency in the assessment of performance across the years, a more complete picture of RWMP performance can be obtained. It is also possible that newer indicators emerge to show additional aspects of progress toward the goal, and these will need to be included as part of the performance measurement.

VIII. Conclusions

Performance measures offer a valuable tool in support of efforts to understand programmatic impact, benefit, and potential for improvement. Stakeholders at the state and local level are eager to benefit from the activities, programs and services being offered by the FHWA Road Weather Management Program. At the same time, the RWMP is eager to see documented evidence that they are achieving the goals set out for the program and satisfying the needs of their constituency. Reflecting early guidance from stakeholders, the eleven metrics examined in this paper are primarily directed to measuring the outcome benefits that the program is providing. But even the most carefully crafted output and outcome metrics can only approximate the concepts they seek to measure. The measures used to support the performance of the RWMP reflect a combination of quantifiable *outputs* (e.g., number of agencies that have acquired an MDSS, or the number of training programs conducted) and qualitative *outcomes* (e.g., the extent to which agencies are using MDSS more effectively throughout their jurisdiction, or the proactive incorporation of road weather information by transportation operators in decision making). In addition, other programs and factors can influence the measured outcomes, presenting a challenge to attribute observed data to the causal effects of the RWMP.

In addition, the responses of the state transportation agencies and stakeholders that are served by the RWMP offer another valuable indicator of program performance. State transportation agency stakeholders who were interviewed were asked to provide suggestions on how the RWMP could better support them. While a few respondents said they wanted more financial support from the RWMP, others sought more of what the program is already providing; namely, more opportunities to participate in programs such as the *Clarus* Initiative and MDSS, more long-distance learning opportunities and technology transfer given that states have severely constrained travel budgets, more direct engagement with the states in addition to channeling support through the private sector, and continued emphasis on ways to enhance and expand information flow and integrate weather into their operations. Overall, these stakeholders seemed pleased with the RWMP's performance, with one respondent saying, "Keep doing what you're doing."

Based on an enhanced understanding of its past performance, the RWMP will be in a position to more effectively move the quality and benefits of the program forward. Even with this first application of the measures, clear progress toward attaining the SAFETEA-LU goals has been demonstrated, and the future forecast for improving performance of the RWMP appears bright.

IX. References

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