Intelligent Transportation Society of America

ITS AMERICA

Weather Information & Applications Special Interest Group (WIA-SIG)

Transportation Weather Research and Development Needs to Support ITS

Version 1.1

Date: 5 November 2005

Prepared by:
National Center for Atmospheric Research

NCAR

VERSION NOTES

Version Number	Date	Notes
Version 1.0	18 September 2005	Initial version prepared for WIA-SIG review
Version 1.1	5 November 2005	Revised version based on comments received by the community

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ACRONYM GLOSSARY

AAR	Association of American Railroads
AMS	American Meteorological Society
ASOS	Automated Surface Observing System
AWOS	Automated Weather Observing System
CRREL	U.S. Army Cold Regions Research and Engineering Laboratory
DOT	Department of Transportation
DSS	Decision Support System
ESS	Environmental Sensor Station
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
GUI	Graphical User Interface
IOC	Initial Operating Capability
ITSA	Intelligent Transportation Society of America
MDSS	Maintenance Decision Support System
METAR	Meteorological Aviation Report (the acronym is French based)
MIT/LL	Massachusetts Institute of Technology - Lincoln Laboratory
NCAR	National Center for Atmospheric Research
NTCIP	National Transportation Communications for ITS Protocol
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
RWIS	Road Weather Information System
SDOT	State Departments of Transportation
SICOP	Snow and Ice Control Pooled Fund Cooperative Program
STWDSR	Surface Transportation Weather Decision Support Requirements
STWRC	Surface Transportation Weather Research Center, University of North Dakota
UTC	University Transportation Center
WIA-SIG	Weather Information and Applications Special Interest Group (ITSA)
WIST	Weather Information for Surface Transportation

NOTICE

This project was conducted by the Weather Information and Applications Special Interest Group (WIA-SIG) with the support of the Intelligent Transportation Society of America (ITSA). The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the information presented herein. The contents do not necessarily reflect the official views of ITSA.

ACKNOWLEDGEMENTS

The project team is grateful for the support and leadership provided by Art Handman, Chair of the ITSA WIA-SIG. The information provided and feedback received by the WIA-SIG members and broader intelligent transportation systems community in support of this project are greatly appreciated.

1 PURPOSE

This document provides a summary of surface transportation weather research activities that are necessary to support and advance Intelligent Transportation Systems (ITS) designed to improve transportation safety, mobility, and efficiency. This report satisfies one of the obligations of the Intelligent Transportation Society of America (ITSA) Weather Information and Applications Special Interest Group (WIA-SIG) Project titled *Surface Transportation Weather Research Program*, which was initiated in August 2004.

2 RELATED DOCUMENTS AND INFORMATION

For additional information on surface transportation weather research, development, and related activities, the reader is directed to the documents listed in Table 1. Additional references are provided throughout this document.

Table 1. Related Documents

Document and/or Web Sites	Primary Source
ITSA Weather Information and Applications Special Interest Group (WIA-SIG) web site: http://www.itsa.org/subject.nsf/0/5d5f7318b6b83cf985256d430065e921?OpenDocument	ITSA
Federal Highway Administration (FHWA) Road Weather Management web site: http://ops.fhwa.dot.gov/weather/	FHWA
National Oceanic and Atmospheric Administration (NOAA) Office of Federal Coordinator for Meteorology (OFCM) Weather Information for Surface Transportation (WIST) web site: http://www.ofcm.gov/wist_report/wist-report.htm	NOAA/OFCM
American Meteorological Society (AMS): *Weather and Highways* Report (2004) http://www.ametsoc.org/atmospolicy/documents/HighwayHighlights.pdf	AMS

National Academy of Sciences, Board on Atmospheric Sciences and Climate (BASC): *Where the Weather Meets the Road – A Research Agenda for Improving Road Weather Services (2004)*, Report http://watson.nap.edu/gateway-portal-unit/portalAction.do?methodToCall=unitReportDetail&skin=basc&link_id=103	NAS/BASC
Surface Transportation Weather Research Center (STWRC), Surface Transportation Weather Workshop Report, University of North Dakota. http://stwrc.rwic.und.edu/workshop/	University of North Dakota (UND)
National Center for Atmospheric Research (NCAR), Symposium on Enhance Weather Information for Improved Railroad Safety and Productivity. http://www.rap.ucar.edu/general/railroadwx/index.html	NCAR
Vehicle Infrastructure Integration (VII) Initiative. Program web site: http://www.its.dot.gov/vii/	FHWA

3 PROBLEM STATEMENT

The U.S. public and its economy are highly dependent on the national highway system. More than 200 million cars and trucks use the national highway system and critical parts of the system function at or near their maximum capacity much of the time [*1*]. Weather reduces capacity and significantly impacts efficiency. Weather is often the catalyst for triggering congestion, particularly for roads operating near capacity.

Weather also plays a critical role in highway safety. In the U.S., each year approximately 7,300 highway deaths and 713,000 injuries are associated with poor weather related driving conditions. The economic toll of these deaths and injuries is estimated at $42B per year [*2*]. Weather plays a role in about 24% of the total crashes and 17% of the total fatalities. Snow, ice and fog contributes to more than 500 million congestion related delay hours. Additional delay is caused by rainfall, which occurs more frequently than snow, ice and fog. These statistics

indicate that the societal and economic impacts of adverse weather on the highway system are huge.

Other modes of transportation are also significantly impacted by weather, as illustrated by the capsizing of a water taxi in high winds on Baltimore's Inner Harbor in the spring of 2004. Of the 25 people onboard, five passengers lost their lives. A service assessment conducted by the National Weather Service (NWS) revealed that forecasters were in "reactive" mode during the event. One of the assessment's key findings and recommendations highlighted the fact that forecasters lacked timely reports of high winds and recommended improved integration of surface reports.

On April 6, 2004, an Amtrak train derailed near Flora, MS killing one person and seriously injuring three others, while 43 of the passengers sustained minor injuries. This one accident alone resulted in approximately $7M in equipment cost. The National Transportation Safety Board (NTSB) concluded that "the inadequately restrained east rail lifted out of the tie plates because of expansion caused by warm temperatures resulting in the rail shifting and the gage widening, causing the wheels of the train to drop between the rails."

The ITSA is deeply concerned about these statistics and strongly believes that an aggressive surface transportation weather research program designed at improving driver safety, and transportation system capacity and efficiency can significantly reduce the impact of weather on the transportation system. Recent advancements in weather detection and prediction, communication and networking, and ITS technologies (e.g., on-board data sampling, telematics, in-vehicle computing, etc.) facilitate the development of new surface transportation weather capabilities.

The technical components necessary to significantly advance surface transportation weather are either in place or quickly emerging. The time is right to begin moving forward to couple advanced weather and Intelligent Transportation System (ITS) technologies.

4 BACKGROUND

There has been a significant increase in the awareness of the need for improved road weather services over the last five to eight years. A coordinated national effort has occurred to highlight the unmet weather needs of the transportation community [1] and identify research requirements and implementation strategies for improved weather services [*3,4,5,6*].

According to the 2004 National Research Council's (NRC) report titled "Where the Weather Meets the Road: A Research Agenda for Improving Road Weather Services" [*3*], the investment required to satisfy the unmet needs for road

weather information is $25M per year for 15 years. An investment at this level would be focused on developing decision support systems for traveler information systems, winter road maintenance, traffic, incident and emergency management, in-vehicle information systems, and ITS.

The atmospheric science community is now actively engaged with the transportation community in a partnership that will accelerate technological improvements. Several key organizations are working together on road weather issues including the American Meteorological Society (AMS), Federal Highway Administration (FHWA), Intelligent Transportation Society of America (ITSA), National Oceanic and Atmospheric Administration (NOAA), National Science Foundation (NSF), National Academy of Sciences (NAS), national laboratories, Aurora Program, National Aeronautics and Space Administration (NASA), Transportation Research Board (TRB), Association of American Railroads (AAR), universities, commercial transportation companies, commercial weather providers, and others.

Surface transportation weather stakeholder groups across the nation are developing research agendas to address technical gaps and unmet users needs. The scope of work and time required to address surface transportation weather varies greatly (from months to decades) depending on the problem, desired solutions and required product fidelity.

The transportation reauthorization bill (SAFETEA-LU) provides funding ($5M per year from 2006 to 2009) to establish a road weather research program to begin developing solutions that will lead to new technologies aimed at improving the utilization of advanced weather information by transportation stakeholders. When initiating this project, the ITSA WIA-SIG sought to;

1) identify surface transportation weather research activities that are highly relevant to the ITS community,

2) document those activities, and

3) disseminate the results so that the ITS community's interests would be considered by organizations and agencies developing surface transportation research programs.

5 DATA GATHERING METHODS

This report utilized information gathered from sources listed in Table 1, references cited throughout the report, and input received from WIA-SIG members. During the fall of 2004, WIA-SIG members were asked to provide surface transportation research topics and supporting information that were

highly relevant to ITSA, achievable, and had the potential, once implemented, to significantly reduce the impact of weather on the surface transportation system.

Feedback was received from a broad spectrum of surface transportation stakeholders representing commercial weather service companies, commercial transportation companies, state departments of transportation, U.S. Department of Transportation, academia, national laboratories, U.S. Department of Commerce, and University Transportation Centers (UTCs).

The majority of input focused on weather research topics that were not specific to any transportation mode (e.g., roadway, rail, transit, etc.) suggesting that progress made within these research areas would benefit all modes. Stakeholder feedback for specific research topics for roadway, transit and rail was also obtained and is included herein.

6 SURFACE TRANSPORTATION WEATHER RESEARCH NEEDS

This section provides a summary of the surface transportation weather research needs identified by WIA-SIG members and other ITS stakeholders. This list is not intended to be an exhaustive list of weather research topics nor does it attempt to define in detail how the research should be performed. Many of the research needs described in this report are also identified as needs in other surface transportation weather research reports and plans.

There was no attempt to prioritize the list of research needs. The list is organized by general topic (e.g., weather modeling, sensor development, human factors, etc.), and for each topic the most relevant transportation mode(s) that would be the primary beneficiary of the results are identified.

6.1 Weather and Surface Condition Sensor Evaluation and Development

Beneficiary Modes:

All transportation modes (rail, transit, highway, pipeline, and marine)

Knowledge Gap:

There is a wide variety of road weather and road condition sensors on the market today and user feedback (primarily state DOT users) strongly suggests that the performance of these devices varies from good to extremely poor. End users have little faith in performance claims made by many vendors and have few independent references available to make sound judgments when evaluating sensor systems. State DOTs are also

worried about sharing data outside the DOT environment because of the uncertain data quality.

There are also other sensors being implemented nationally that have the potential for being used to derive weather and surface conditions (e.g., video cameras, and traffic sensors); however, little research has been conducted to date to determine the utility of these data for these purposes.

Research Needs:

Sensor evaluations are required by neutral parties (e.g., testing laboratories, national weather research laboratories, and/or universities) to evaluate the performance of existing and emerging Environmental Sensor Station (ESS) technologies. Sensor performance studies in a variety of climates over long time periods (multiple seasons) are required to assess the technical performance of a variety of weather and road condition sensors in highly variable weather conditions. Sensor testing environments should be established and designed to support evaluations for long time periods as this will provide ongoing opportunities to test sensor enhancements and new sensor technologies under consistent test conditions and will allow the reuse of the testing infrastructure, which will reduce costs.

In addition to performing evaluations of existing or emerging commercial sensors, research is required to develop advanced weather and road condition sensing systems. Moreover, this research will support the development of standards associated with sensor siting, calibration, and maintenance. State DOTs have expressed a strong desire for a national ESS testing facility as they currently have low confidence in ESS data integrity and few options for obtaining objective and reliable technical performance information.

Primary Benefits:

- ✓ Well documented performance results of current and emerging weather and pavement sensing systems
- ✓ Development of improved sensing systems
- ✓ Confidence in data quality
- ✓ Reduced risk associated with data sharing

6.2 Weather and Surface Condition Data Integration

Beneficiary Modes:

All transportation modes (rail, transit, highway, pipeline, and marine)

Knowledge Gap:

Weather and surface condition data are collected by hundreds of organizations across the nation. Acquisition of these datasets is difficult because 1) each organization must be identified and contacted, 2) a wide range of data protocols and standards is used, 3) little is known about data quality, and 4) data sharing rules are often burdensome. These constraints make it very difficult to utilize these data and hinder the development of (seamless) nationwide surface transportation weather and surface condition products.

Research Needs:

Research is required to evaluate, design, test, and demonstrate a data acquisition, quality control, and dissemination infrastructure for weather and surface condition data. The research program should be designed to coordinate regional weather and environmental observing networks, which are proliferating around the country. The research program should define metadata guidelines, evaluate quality control techniques, investigate data integration methods, and gather archiving requirements.

Note: The FHWA initiated the *Clarus* Initiative [*7*] in 2004 to address many of the needs expressed under this research area. The WIA-SIG supports this effort.

Primary Benefits:

- ✓ Ability to access reliable surface transportation weather and surface condition observations nationwide
- ✓ Continuous quality control of observations
- ✓ Real-time data to support transportation decision support systems
- ✓ Single access point for national data acquisition

6.3 Standard and Guidelines

Beneficiary Modes:

All transportation modes (rail, transit, highway, pipeline, and marine)

Knowledge Gap:

A variety of data protocols, formats, and standards are currently being used to collect, process, disseminate, and archive weather and surface (primarily road) condition data (observations and forecasts). The lack of consistent standards and/or guidelines makes it very difficult to acquire and process these data. A variety of data formats and protocols are also used within the meteorological community further complicating the issue.

Several state DOTs provide weather and road condition information on web sites and roadside kiosks. There are currently no guidelines for how this information should be presented or how surface conditions should be described. The lack of consistency makes interpretation of the information very difficult, especially when travelers cross jurisdictional boundaries.

Research Needs:

There has been a focus on standards for a few years and several projects have been initiated to begin addressing this problem. Examples of RWIS data standardization projects are provided below:

- ✓ ESS Siting Guidelines [http://ops.fhwa.dot.gov/publications/ess05/ess0501.htm]
- ✓ NTCIP-ESS 1204 [http://www.ntcip.org/library/standards/default.asp?documents=yes&qreport=no&standard=1204]
- ✓ Road Web Markup Language (RWML) [http://www2.ceri.go.jp/eng/its-win/pdf/15e.pdf]
- ✓ Canadian Meteorological Markup Language (CMML)

Continued research, development, and enhancement of standards are required to facilitate access to weather and surface condition data and to ensure interoperability between sensing platforms. Current projects have focused on standards for observations. Data standards will soon be required for surface transportation weather and surface condition prediction products. Information presentation standards are also required to ensure that weather and surface condition information is presented in a consistent manner between jurisdictions, and between providers within single jurisdictions.

Primary Benefits:

- ✓ Facilitates easy access to weather and surface condition data
- ✓ Reduces complexities associated with fusing data from a variety of sources
- ✓ Supports interoperability between sensing platforms
- ✓ Provides consistent descriptions and presentations of weather and surface conditions to end users

6.4 Vehicle Sensed Weather and Surface Conditions

Beneficiary Modes:

Rail, transit, highway, and marine

Knowledge Gap:

There is great anticipation concerning the potential benefits of utilizing weather and surface condition data measured from vehicles. Telematics technologies and more recently the Vehicle Infrastructure Integration (VII) Initiative [*8*] provide a framework for utilizing mobile data. Traditionally, surface weather and road condition data are measured at airports (e.g., ASOS) and along roadways (e.g., ESS and RWIS). Large spatial data gaps exist between fixed sensor sites and the quantity of fixed sites will never be sufficient to measure small-scale weather and surface condition phenomena such as fog, black ice, snow drifts, high cross-winds, etc.

Little is known about the quality of vehicle-based measurements and the type of information that could be derived from vehicle databases. In addition, there is a lack of information about the amount of market penetration (e.g., number of equipped vehicles) that may be required to derive reliable weather and surface condition measurements. Significant research is needed to fully understand and exploit vehicle based data.

Research Needs:

Research is required in numerous topics related to vehicle based data. Research needs to be conducted on the following topics (this list is not exhaustive):

- Identification of vehicle data that could be used alone or in combination to measure weather and surface conditions
- Evaluation of the accuracy of various vehicle data types under a variety of weather and driving conditions
- Development of concepts and assessment of the feasibility of utilizing vehicle data

- Development of quality control techniques for vehicle data
- Development of metadata for vehicle data
- Evaluation of communication requirements for exporting and importing data to and from vehicles
- Evaluation of how exported vehicle data could be utilized by weather and road condition prediction systems

Primary Benefits:

- ✓ Improved safety and mobility
- ✓ Ability to identify weather and surface condition hazards and convey the information to the driver (within the vehicle environment)
- ✓ Ability to better define current weather and surface condition hazards by utilizing vehicle data and combining it with external (to the vehicle) data
- ✓ Improved weather and road condition prediction products

Note: The FHWA will begin some exploratory work in FY2006 on the weather related topics associated with vehicle Vehicle infrastructure Infrastructure Integration. The WIA-SIG supports this effort.

6.5 In-Vehicle Weather and Surface Condition Hazard Information

Beneficiary Modes:

Rail, transit, highway, and marine

Knowledge Gap:

Little research has been performed to develop capabilities that will allow weather and road condition hazard information to be provided to drivers in near real time. The potential safety benefits of informing drivers when dangerous conditions exist along their travel route could be very large. Research is needed for all aspects of this problem from identification of hazards to the human factor issues related to presenting the information to drivers.

Research Needs:

Research is required in several areas including, but not limited to:

- Identification of weather and surface condition hazard types that could and should be presented to drivers
- Development of algorithms that generate products utilizing on-board data
- Development of algorithms that generate products utilizing both on-board and off-board data

- Development of algorithms to integrate weather and surface condition hazard information with navigation systems
- Human factors associated with the presentation of hazard information to drivers
- Human factors associated with various information presentation methods (e.g., audible alerts, text alerts, voice response, moving map displays, etc.)

Primary Benefits:

- ✓ Improved safety by informing drivers of impending weather and surface condition hazards

- ✓ Improved mobility by informing drivers of hazards allowing drivers to avoid, where practical, hazardous regions. When combined with navigation systems the mobility benefit would be enhanced

6.6 Transportation Network Modeling

Beneficiary Modes:

Highway, transit, rail, and marine (e.g., river and waterways)

Knowledge Gap:

Only a few studies exist that evaluate the impact weather has on traffic operations [*9,10*] and these studies only address limited aspects of the problem. Little is known about the optimal control strategies that could be used in different weather and surface conditions that could improve transportation system safety and capacity.

Research Needs:

Research is needed to explore the overall impact weather has on traffic operations (flow rates, congestion, capacity, speed, crash rates, etc.). In addition, traffic modeling studies should be performed to evaluate advisory and control strategies that could be utilized to optimize transportation system performance under varying weather and surface conditions. Candidate advisory and control strategies for investigation include weather-responsive traffic signal timing, ramp metering, dynamic message signs, variable speed limits, road closures, contra flow, etc.

Primary Benefits:

- ✓ Improved transportation system safety

- ✓ Improved system mobility and efficiency
- ✓ Reduced congestion during adverse weather and surface conditions

6.7 Human Factors

Beneficiary Modes:

Highway, transit, rail, and marine

Knowledge Gap:

Very limited human factors research has been conducted to evaluate the type of weather and surface condition information that is desired by transportation decision makers. Research is required to ensure critical public safety information reaches end users whether at home, work, using public transportation or in vehicles.

Research Needs:

Human factors research is required to assess information dissemination capabilities and alternatives for a variety of weather and surface condition products. Human factors research is required in several areas including, but not limited to:

- Determination of the type of weather and surface condition information required by various categories of end users (traffic managers, incident managers, maintenance, travelers, etc.)
- Evaluation of methods and techniques for presenting the information to various user categories
- Evaluation of deterministic versus probabilistic products
- Evaluation of product and display concepts for in-vehicle information systems including capabilities to integrate weather and surface condition information with navigation systems
- Determination of optimal product presentation concepts for representing weather and surface condition information
- Determination of the appropriate options to be taken by vehicle operators provided with advanced weather and road condition hazard information
- Evaluation of required training for various categories of end users

Primary Benefits:

- ✓ Improved acceptance of weather and surface condition products
- ✓ Improved safety by raising market penetration of safety and efficiency-related products

- ✓ Better management of user expectations for weather and surface condition information
- ✓ Improved safety by optimizing presentation methods, particularly with respect to in-vehicle information systems whereby driver distraction issues are addressed
- ✓ Improved safety of tailoring weather and surface condition information for various categories of end users

6.8 Decision Support Systems

Beneficiary Modes:

All transportation modes (rail, transit, highway, pipeline, and marine)

Knowledge Gap:

Weather and surface condition information is generally not well integrated with other information systems used by the transportation community. This leads to stove piping where users must access weather through separate systems. The lack of integration complicates an already difficult operation. Weather and surface condition information needs to be integrated into the decision process and products must be tailored for individual decision makers (e.g., traffic, incident, and emergency managers, maintenance personnel, dispatchers, and travelers). The FHWA winter Maintenance Decision Support System (MDSS) [*11,12*] is a good example of a decision support system related research project that involved a broad group of stakeholders resulting in a suite of capabilities (e.g., prototype code, system specifications) designed to improve the performance of snow and ice control operations.

Research Needs:

Research is needed to build upon the Surface Transportation Weather Decision Support Requirements (STWDSR) project and the Weather Information for Surface Transportation (WIST) National Needs Assessment Report, which identified a broad range of user requirements for surface transportation weather services (all modes). Research is required to develop detailed functional requirement specifications (for each user category) for weather and surface condition decision support systems. Rapid prototyping and field operational demonstrations should be used to validate and refine requirements. Research results (functional specifications, code, etc.) should be made available to the community to facilitate adoption and speed implementation.

Decision support systems technologies and capabilities should be developed for multiple user categories of all transportation modes including maintenance, traffic, incident and emergency management, construction, dispatch (e.g., transit and rail), and travelers (including commercial vehicle operators).

Decision support system technologies are needed to support a large variety of decisions covering a large variety of weather and surface condition phenomena including, but not limited to:

- Expansion and contraction of rails
- Surface temperature extremes
- Blowing and drifting snow
- Snow depth (on roadways, rails, switches, etc.)
- Ice formation (on roadways, rails, switches, etc.)
- Fog and low visibility
- Hail
- Precipitation
- Flooding
- Washouts
- Debris flows
- Pavement temperature
- Precipitation type (snow, rain, ice, freezing rain and drizzle, etc.)
- Frost formation (on roads, bridges, rails, etc.)
- Soil freezing and frost heaves (load restrictions)
- Lightning
- High wind (high profile vehicle and rail car blow-over, spraying restrictions, etc)
- Smoke and hazardous plumes

Primary Benefits:

- ✓ Improved safety
- ✓ Improved efficiency
- ✓ Improved capacity
- ✓ Reduced congestion
- ✓ More efficient operations for decision makers
- ✓ Reduced operational and maintenance cost

6.9 Weather and Surface Condition Detection and Prediction

Beneficiary Modes:

All transportation modes (rail, transit, highway, pipeline, and marine)

Knowledge Gap:

The accuracy of weather forecasts is generally improving; however, sufficient forecast uncertainty still exists, particularly beyond 24 hours, reducing the utility of many forecast products. Weather information near the surface (from the surface to a few feet above the surface) is most critical for surface transportation. Additional research is required to understand the impact weather has on surface transportation. Precipitation information (start time, stop time, type, rate, and accumulation) is extremely critical to the surface transportation community, but it is poorly predicted. Precipitation is also poorly detected as there are large gaps in the in-situ precipitation measurement network across the nation and gauges often perform poorly during winter conditions. Remote sensing of precipitation, which mainly includes radars, has limited accuracy because precipitation type, rate, and accumulation has to be derived from radar data and numerous assumptions are made to estimate precipitation amount.

Improvements in the detection and prediction of key weather elements will naturally improve the utility of transportation related decision support systems that incorporate weather and surface condition information.

Research Needs:

Research is required to improve the accuracy, specificity, and timeliness of weather detection and prediction products. The focus of the improvements must be on the surface or near surface variables. Improvements in quantitative precipitation forecasts and precipitation detection are most critical to all transportation modes. Research is also required to determine the optimal mix of observations that are needed to derive critical weather and surface condition hazards.

Straightforward access to high quality national weather and surface condition observation data is also critical as these data will become the building blocks of high-resolution surface transportation hazard analysis products. Research is required to determine how to integrate and blend disparate datasets to create high-resolution analyses that can feed other systems such as 511, decision support systems, in-vehicle information systems, rest stop kiosks, etc.

The WIST Report [*1*] provides detailed information on the types of weather information that are needed by various user categories, so this information is not repeated herein. A few of the most critical items needing improvement as suggested by WIA-SIG members are listed in the table below.

High priority weather and surface condition improvements

Item	Detection	Prediction
Weather		
Precipitation type	X	X
Precipitation rate	X	X
Precipitation amount (liquid)	X	X
Precipitation accumulation (liquid & solid)	X	X
Cloud cover		X
Insolation (direct and indirect solar radiation)		X
Visibility/Fog	X	X
Relative humidity/dew point		X
Plume dispersion	X	X
High winds	X	X
Surface Condition		
Pavement temperature	X	X
Rail temperature & variability	X	X
Soil moisture and temperature	X	X
Frost formation	X	X
Dew formation (on pavement)	X	X
Ice formation	X	X
Blowing and drifting snow	X	X
Flooding	X	X
Hazardous plume tracking/chemical type	X	X
Pavement condition (wet, snowy, icy, etc.	X	X

Primary Benefits:

- ✓ Improved weather detection
- ✓ Improved weather prediction
- ✓ Improved decision making by all stakeholders
- ✓ Improved safety, mobility, and efficiency of the transportation system

6.10 Benefits of Improved Weather and Surface Information

Beneficiary Modes:

All transportation modes (rail, transit, highway, pipeline, and marine)

Knowledge Gap:

There is consensus among the surface transportation stakeholders that improved weather and surface condition detection and prediction information will improve the surface transportation system. What is not known is how much economic impact improved surface transportation weather information (current weather and surface conditions and forecasts) will have on specific operational segments of the transportation community. Knowledge of the economic impact of improved weather and road condition information on traffic, incident and emergency management, dispatch and maintenance operations, and on travelers is critical for policy makers and for supporting decisions on where to invest limited road weather research resources.

Research Needs:

The primary objective of the research is to identify and quantify end user benefits of improved road weather information on transportation operations. The analysis would be performed systematically for each major operational category including traffic, incident, and emergency management, dispatch, and maintenance operations. Analyses would also be performed to assess the benefits and use of improved surface transportation weather information for travelers including commercial vehicle operators.

The application of appropriate economic research methods can significantly improve the knowledge base of benefits and costs of surface weather forecasts. A small number of high quality quantitative case studies can provide a framework for assessing the costs and benefits of road weather forecasts under a range of information uses.

Weather forecasts are moving into an era of communicating the uncertainty inherent in forecast information. The communication of uncertainty information can add value to decision making but also has the potential to overload decision makers. Primary research is needed on the appropriate types and amounts of uncertainty information decision makers can use and how best to communicate that information to them.

Primary Benefits:

- ✓ Understanding of economic benefits/costs for research investments
- ✓ Guidance for policy makers
- ✓ More informed investment decisions

7 SUMMARY

Over the next decade, the surface transportation system will move away from being mainly a reactive system to a proactive system with respect to weather and its impact on surface conditions. The rapid rise in awareness of the impact of weather on the transportation system and the new relationships that are developing between the weather and transportation communities, provide a significant opportunity for improving surface transportation weather services.

The research and development activities summarized in this report, if acted upon, will greatly improve transportation safety, efficiency and mobility, and will make the nation's transportation system more resilient to adverse weather and surface conditions.

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