Surface Transportation Weather Decision Support Requirements

Draft Version 1.0

User Needs and Appendices

Advanced-Integrated
Decision Support
Using Weather Information
for
Surface Transportation
Decisions Makers

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for

Paul Pisano, Coordinator
Weather and Winter Mobility Program
Office of Transportation Operations
Federal Highway Administration

by
Mitretek Systems, Inc.

Contacts

The following people should be contacted for any further information or to supply comments on this document:

Paul Pisano
Federal Highway Administration
HOTO-1
400 Seventh St. S.W.
Washington, DC 20590
Tel: 202 366-1301
Fax: 202 366-8712
paul.pisano@fhwa.dot.gov

Gary G. Nelson
Mitretek Systems
600 Maryland Ave. S.W., Suite 755
Washington, DC 20024
Tel: 202 488-5718
Fax: 202 863-2988
gnelson@mitretek.org

Summary

The full Executive Summary of the STWDSR V1.0 report is published as a separate document. It can be found as document 11823 in the Electronic Documents Library (EDL) at http://www.its.dot.gov/welcome.htm. This document contains only the user needs material. A brief project summary is below:

Summary

The Federal Highway Administration (FHWA) of the U.S. Department of Transportation (USDOT) has a responsibility to coordinate and promote projects that will bring the best information on weather to decision makers, in order to improve performance of the surface transportation system.

To fulfill its responsibility, the FHWA's Office of Transportation Operations (HOTO) Weather and Winter Mobility Program is documenting the weather information requirements of all road users and operators under this Surface Transportation Weather Decision Support Requirements (STWDSR) project. The STWDSR project is being conducted for the FHWA by Mitretek Systems, Inc. Developing requirements through the STWDSR project will support the Weather and Winter Mobility program by:

1. Promoting deployment partnerships between users, private vendors and non-profit meteorological systems developers to realize advanced surface transportation weather decision support system concepts;

2. Producing deployment guidance for local public/private development of the advanced system;

3. Guiding further federal research projects and operational tests, and;

4. Helping coordinate surface transportation weather requirements and projects across federal agencies, especially with the National Weather Service (NWS).

The advanced system will be conceptualized within the Intelligent Transportation System (ITS). The initial phase of this project has enumerated needs for weather information across all surface transportation decision makers. Requirements development will focus on winter road maintenance managers for a deliverable (the version 2.0 of this document) in June, 2000. The user needs material extracted from the full report follows.

User Needs

User needs are translated into requirements on a conceptual system called the Weather Information for Surface Transportation Decision Support System (WIST-DSS). The potential users of the WIST-DSS are people, or automatic controllers, who use information on weather and the surface transportation system to make decisions for the sake of exercising control over some aspect of the transportation system. User needs are defined as decisions and categorized in a way to aid WIST-DSS requirements derivation.

1. Needs and Requirements

The STWDSR project distinguishes needs from requirements:

A *requirement* is a qualitative or quantitative attribute allocated to subsystems (any functional, logical or physical partition) of the WIST-DSS and its interfaces to other-ITS or outside-ITS subsystems. Requirements ultimately are validated against performance of the surface transportation system.

A *need* is an expression by decision support system users for a service that will improve their contribution to surface transportation system performance. The STWDSR translates needs to requirements. The STWDSR defines needs as decisions involving weather information.

2. Needs and Goals

Needs respond to transportation system goals (outcomes) and are served by the system being specified. This is illustrated in the figure below:

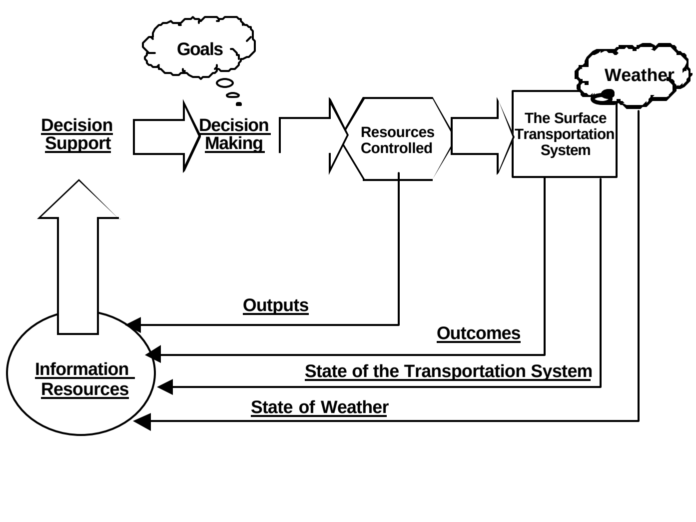

Figure 1: Structure of Goal-Oriented Decision Making

The focus is on the decision maker. The decision maker compares goals with the system state via decision support systems. The STWDSR focuses on decisions relating to weather and the transportation system, and initially on treatment decisions for winter road weather, meaning primarily snow and ice. The STWDSR deals with the WIST-DSS as the information system to support the treatment decisions. The decision maker usually will be a human in this case, but could also be an automatic control device.

3. Needs Sources

The easiest way to move from needs to requirements is to define needs as decisions, because decisions are what need decision support. Needs as decisions carry the goals into the WIST-DSS. Although requirements initially will be developed only for winter road maintenance decisions, a full needs list is developed for surface transportation and contained in the Appendix. The process to define needs uses three approaches:

1. Needs follow from goals allocated to institutions and their decision makers, so needs can be derived from stated goals translated to the kinds of decisions needed to meet those goals.

2. Decision support projects (e.g., ITS projects, or the process specifications in the National ITS Architecture) directly imply the kinds of decisions that are made and that need decision support.

3. "Needs" lists exist for weather information, and often were not created within the framework used here. But these can be combed for those needs that are decisions in need of decision support.

Some source analysis and the resulting needs list is also contained in the Appendix. However, it is useful to show here the first approach applied to the FHWA goals:

Table 1: Needs for Weather Information Derived from the FHWA Goals

FHWA Strategic Goal		
	FHWA Objective	
		derived need (decision)
1. Mobility		
	1a. Preserve and enhance the infrastructure...with emphasis on the National Highway System (NHS)	

		Climatological information relevant to infrastructure design and maintainability. Predictive information for construction scheduling and integrity of construction materials.
	1b. Improve the operation of the highway systems and intermodal linkages to increase access	
		Current and predictive information on all weather attributes that: require highway maintenance treatment; require repair of structures or pavements; require control settings or interventions, or; affect the service and schedules of intermodal services by which connections are made.
	1c. Minimize the time needed to return highways to full service following disasters	
		Current and predictive information on weather threats to highway pavements, structures and control systems. Current and predictive information on weather attributes relevant to HAZMAT remediation. Decision support coordination with other response agencies.
2. Safety		
	2a. Reduce the number of fatalities and injuries	
		Current weather information relevant to immediate warnings on driving conditions. Predictive weather information relevant to road conditions and visibility for advanced route and schedule planning by travelers. Current and predictive information for highway maintenance to alleviate threats to driving safety and prompt repair of weather-related outages and defects. Current and predictive information to highway operators for control interventions. Current weather-related road surface and visibility conditions for enforcement of speed limits. Current and predictive weather-related road surface and visibility conditions for road closures. Archival weather data for crash analysis to devise design and control strategies.
3. Productivity		
	3a. Improve the economic efficiency of highway transportation	
		Predictive information on weather-related highway transportation times, with explicit uncertainty, for scheduling production and transportation. Predictive information on weather conditions affecting integrity of loads. Predictive information on road conditions and status for efficient route and schedule planning by travelers. Predictive information on weather related to event planning for advanced cancellation of unnecessary trips.
	3b. Improve the return on investment of the highway system	
		Weather information as cited above for efficient highway maintenance, operations and use.
4. Human and natural environment		
	4a. Enhance community and social benefits of highway transportation	
		Weather information as cited above for efficient highway maintenance, operations and use.
	4b. Improve the quality of the natural environment by reducing highway-related pollution and by protecting and enhancing ecosystems.	
		Current and predictive weather information to minimize applications of ice-treatment chemicals and grit. Current and predictive weather information to increase effectiveness and reduce dispersion of herbicides. Predictive weather information that factors into air pollution control strategies, both climatological for SIP strategies and meso/synoptic for tactical mitigations concerning traffic demand management, maintenance and construction activities. Climatological data for highway location and design that mitigates runoff, erosion and other environmental impacts of highways. Current and predictive weather information relevant to efficient response to HAZMAT spills and plumes.
5. National security		

	5a. Improve the capacity and operation of the highway system to support mobilization	
		Predictive weather-related road condition and visibility for planners of surface mobilization movements regarding weight limits, speeds, routing, scheduling and integrity of loads. Weather conditions affecting air and maritime transport connections.

In the case of winter road maintenance, not all requirements deriving from the goals will apply to the WIST-DSS. There may be operational practice, institutional organization, training, other ITS improvements, non-ITS improvements that should be pursued to meet the goals. These will be identified throughout the process, as part of the "outer spiral" in a spiral development process, leading to the STWDSR V2.0

4. Decision Maker Categories

The list of needs in the Appendix was created by defining the list of all possible surface transportation decision makers, applying scale categories, and then listing the decisions that each decision maker must make within a scale category. The list of decision makers emerges from considering all the previous needs compilations. The list is based primarily on working back from outcomes, in terms of the kinds of resources controlled. For instance a traveler controls trip itineraries, and a maintenance manager controls road treatment resources. The categorization of decision makers has the unfortunate effect of partitioning consideration of the WIST-DSS more by outputs than by the kinds of decision support needed. However, the STWDSR is based on operational scenarios that do relate to kinds of outputs. Based on consideration of all needs documentation, the following hierarchical list of decision makers was created:

Index	Decision Makers
1.0	Infrastructure Operators
1.1	Highway maintainer (winter)
1.2	Highway maintainer (other)
1.3	Traffic manager
1.4	Information system manager
1.5	Traffic device controllers
1.6	RWIS Maintainer
1.7	Rail maintainer
1.8	Waterways operator
2.0	Infrastructure Builder/Planner
2.1	Transportation designer
2.2	Transportation builder
2.3	Transportation planner
2.4	Transportation evaluator
3.0	Information service provider
4.0	Fleet Operators
4.1	Transit-fixed
4.2	Transit-demand responsive

4.3		School bus/district manager
4.4		Commercial fleet dispatcher
4.5		Railway dispatcher
4.6		Barge dispatcher
4.7		Military movement managers
4.8		Hazardous/special cargo managers
5.0	Vehicle operators	
5.1		Highway drivers
5.2		Vehicle control system
5.3		Train engineers
5.4		Barge and boat navigators
6.0	Travelers	
6.1		Traveler awaiters
6.2		Personal traveler/recreational
6.3		Personal traveler/commuter
6.4		Personal traveler/business
6.5		Personal traveler/discretionary
7.0	Incident/emergency response	
7.1		Emergency medical dispatcher (PSAP)
7.2		Public safety dispatcher
7.3		Infrastructure incident dispatcher
7.4		Disaster evacuation manager
7.5		Disaster response manager
7.6		Search and rescue manager
7.7		Insurer
8.0	Activity managers	
8.1		Special event planner
8.2		Recreation managers
8.3		Retail managers
8.4		Production manager-industrial
8.5		Production manager-agricultural
8.6		Brokerage and futures
8.7		Power system managers

This list can be used to organize further operational analyses and requirements. This project is focused on decision maker type 1.1, and must consider coordination with all other types via the ITS.

5. The Scale Concept

The Weather Team White Paper articulated the scale concept [pp. 31 et. seq.]. With user type, the scale concept is the other primary categorization of needs.

The physics of weather determines certain space-time relations for weather phenomena: Spatially small weather events develop and dissipate quickly. These include severe convective storms (tornadoes, thunderstorms, hail storms) and other cases of large changes (gradients) in weather attributes over small spatial volumes. These cases have limited time horizons of reliable predictability. This is the meso scale. At the smallest scale (micro scale), minimal processing of direct observational information is necessary (e.g., wind shear and micro burst detection at airports or highway fog detection and warning).

Persistent systems, with longer time horizons of reliable predictability are larger in spatial area (e.g., large air masses and their frontal weather). This is the synoptic scale, typically forecast twice a day, for national regions and out to horizons of days. Beyond that is the seasonal or climatic scale. These longer horizon forecasts are coupled with coarser spatial resolution, and give weather attributes as averages for large areas. The physics of weather, coupled with information collecting and processing limitations determines that spatial localization and accuracy of weather attributes go together with smaller analysis regions and shorter predictive horizons, and conversely. The idea of scale is therefore a fundamental attribute of weather information that specifies what is needed to get the information and how far the information is reliable.

From the decision perspective, all decisions are based on past information in order to affect future resource controls and system states. Resource deployment also has a "physics" that defines characteristic space and time scales. For instance, crews can be called-up and dispatched to their beats only in time horizons related to crew scheduling, commuting time, equipment speed and beat geography. When weather combines with the transportation system, space-time scales of outcome response are imposed. For instance, snowfall rate and highway network size, relative to the maintenance crew resource, determine how quickly a level of service can be achieved.

Efficiency considerations on resource use (e.g., the cost of crews and materials) determine how much accuracy of the information can be afforded, subject to the scale limits of weather information. While this can be a very complicated problem for benefit-cost analysis, in practice there is a prevalent quality of weather information at each scale. It is a question of assuring that a decision maker uses the best available information at the appropriate scale. Stovepiping, that prevents integrated access to information across the scales, may be the biggest barrier to this. The improvement of weather information at any scale is a function of technical advance in weather physics and computer power, coupled with investment in observational data. The physics and computer advances tend to be exploited fairly rapidly in the meteorological field.

Anything that is a barrier to matching decision and information scales will reduce efficiency. This also applies to decisions that do not respond with appropriate risk considerations to the uncertainty inherent at each scale, or that try to stretch information from smaller to larger scales without considering the real loss of reliability. This is common when forecast grids are arbitrarily interpolated to finer resolution, where point observations are stretched to large areas, or where observations are extrapolated too far into the future. Sometimes the data just are not there, but it is essential that DSS provide the next best source.

There is a continuum of space-time scale. However, weather information has a conventional set of discrete scale categories, defined as follows (with some liberties given the imprecision of the scale category boundaries) and matched to decision-scale regimes:

- Micro scale: sub-hour (minutes) time horizons and local areas (<few kilometers). Typifies

severe convective events (e.g., micro-bursts) and safety-critical controls (e.g., vehicle operation) or local adaptations of treatments (e.g., speed- and surface-temperature controlled chemical applications).

- Meso scale: approx. 1-12 hour time horizons and few-to-hundreds of kilometers areas. Typifies convective storms and moderately-high gradients of effects (e.g., snow bands with large spatial variation). Includes many operational decisions of interest in transportation (e.g., resource dispatching).

- Synoptic scale: 12 hour-week(s) time horizons and continental areas. Typifies large air masses and frontal weather. Transportation-operational decisions tend to overlap between synoptic and meso scale, but decisions for surface transportation in this scale generally concern response-preparation or travel planning.

- Climatic scale: beyond weeks in time horizon and up to global (and extraterrestrial) area. Surface transportation decisions in this scale typically concern planning of fixed assets and facilities, advanced purchasing and advanced travel planning.

While the space-time rule of longer time and larger area holds, there are variations on how the dimensions can be mixed. For instance, climatic scale information can refer to spatially-local points (e.g., the freezing climatology of a road on bridge structure as opposed to on soil in a cut, or fog obscuration on bridges over rivers). Nonetheless, climatic forecasts are specified by averaging long time series of information (long horizon). This time series cannot determine a condition at a specific time. Climatological models use statistical relations from long time series to estimate variations around local (micro-scale) observations. For instance, "thermal mapping" is used to extend point ESS measurements over route segments. Model Output Statistics (MOS) products result from regression relations between sets of model forecasts and their validated results, and typically are presented as the ranges (e.g., a standard deviation of temperature) that may result when the model gives a point prediction. These kinds of products carry with them the statistical risk of the model. Observational assimilation does the same for point observations, by giving a risk parameter (like a standard deviation range) to an observation based on how much it disagrees with its surrounding observations and other model forecasts.

The Weather Team White Paper defined three categories of decision scale: warning (micro), operations (meso/synoptic) and planning (climatic). For transportation decisions it is typical that the micro- and climatic scales are relatively distinct while the meso and synoptic scales overlap. The synoptic scale has conventionally been defined by a twice-daily observational cycle and forecast model initialization. The advent of continuous remote sensing has blurred this distinction, and there is now much more variety in the regional scope, resolution, time cycle and time horizon of numerical modeling.

A lot of surface transportation decision support has focused on numerical atmospheric modeling to improve the range of scale choices down from the synoptic to the meso scale. This has diverted attention from filling the micro-to-meso scale gap by better processing of observations, especially from remote sensing (radar and satellite). There are cases where a finer scale is misused for large scale decisions (the typical "look out the window" for regional dispatching), or where numerical models are used at near horizons and very high resolution in place of micro scale observations, or where the models themselves mismatch resolution, horizon and update cycles. In any case, the risk parameter associated with scale will be the clue as to how well the match is made.

The figure below indicates some of the kinds of decisions in each of scale range:

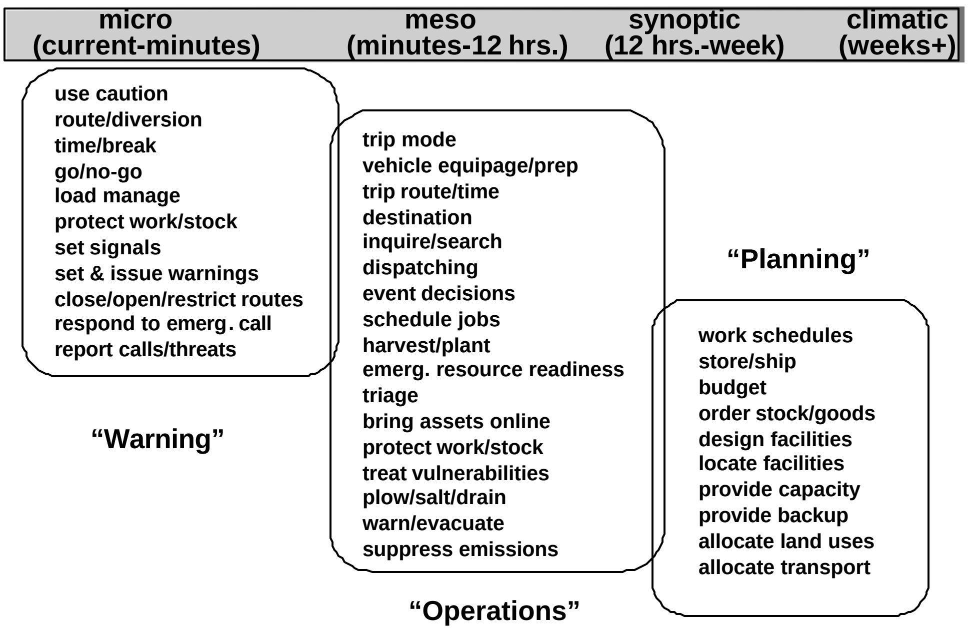

Figure 2: Meteorological Scales and Categories of Decisions

6. The Matrix of User Decisions and Scale

Needs as decisions and decisions categorized by decision maker and scale determine the structure of a matrix to list needs. Decisions are the cell entries with scale as the column headers and decision maker types as the row headers. The decision derivation was also helped by considering the generic kinds of actions possible in transportation decision making with respect to weather:

- Treat: To act upon transportation facilities in a way to mitigate the effects of weather on the outcome goals: Examples are ice treatment, snow removal, snow fence installation, standing-water pumping, flood control.

- Respond: To mitigate a negative effect of weather on a transportation outcome when it has occurred. Examples are repair of storm damage, restoration of power/communication circuits, search and rescue.

- Cope: To alter transportation activities because weather has limited options or reduced service on the transportation system. Examples are rescheduling activities, changing routes, changing destinations.

- Seek: There are cases where weather creates opportunities on the transportation system. Examples are recreational trips that pursue sports like sailing, surfing, skiing or skating. Weather and road conditions may be sought for research, treatment or response preparation. While this is a distinct use of weather information, it can be treated as a precursor to the other activities.

The structure of the needs table in the appendix therefore is as shown below:

	Scale		
Decision Maker	*Micro (Warning)*	*Meso/Synoptic (Operational)*	*Synoptic/Climatic (Planning)*
(hierarchical list)	treat: cope: respond: seek:	treat: cope: respond: seek:	treat: cope: respond: seek:

The full matrix is in the Appendix. The table contains indices for both decision-maker type and the decision by scale. All entries in the matrix can be specified by the index with format (T.t.S.d) where (T.t) is the major and minor decision-maker Type index. S is the scale index (1 = micro/warning, 2 =

meso/synoptic/ operational, and 3 = climatic/planning). The (d) index is a sequential number for the particular decision. The table currently contains 44 decision maker types and 423 needs (decisions).

Many kinds of decisions are generic over decision maker types. Identifying clusters of decision types should guide further requirements analyses. Transportation system managers (as opposed to vehicle drivers), maintainers (possibly integrated with other incident respondents), fleet dispatchers and travelers (including vehicle drivers) are the main categories that could be considered.

For winter road maintenance, the decisions are almost all of the treatment type, but span the scales in the three general categories:

- Immediate control of treatment applications combined with truck control (warning/micro scale);
- The scheduling, preparation and dispatching of treatment resources (operational/meso-synoptic scale);
- Decisions on staffing, facilities, equipment fleets, and material inventories that determine what treatment activity is feasible at any time (planning/climatic scale).

Information clearly should be integrated across these categories. For instance, onsite treatment observations are the basis for larger scale decisions and ultimately the source of climatic-scale information. Planning must be based on performance that is a function of both micro-scale treatment and the meso/synoptic scale management. However, the DSS in a vehicle (or for a fixed chemical spray system or warning system) will be different in many ways from a maintenance-office system, or a resource planning system.

There is also an issue of what outcomes become dominant goals at what scales, rightly or wrongly. A very local focus tends to promote excessive chemical application and scraping when those resources may need to be allocated more strategically. At the budgeting level (climatic), if there is too little investment in treatment resources, the outcome costs concerning crashes and mobility (almost certainly the major cost components) increase severely. Yet budgeting tends to magnify the direct treatment costs and limits treatment capability (there may also be risk-bias effects here given climate variability). Climatic information (including its uncertainty) could do much in matching investments to weather threats on a seasonal aggregate, potentially with great outcome savings. Otherwise, coordination (borrowing resources, managing traffic under weather threats) and efficiency in treatment at the operational and micro-scales must cope with resource constraints. These examples suggest how integration must occur across the hierarchy of scales, even if separate decision makers are making different decisions with different scales of information. This kind of hierarchical decision system adds new dimensions to DSS design.

12.0 Appended Materials

12.1 Needs Derivation Sources

Needs for the WIST-DSS are derived according to the approach described in Section 4. Sources for these approaches are analyzed below. Note that most sources do not maintain the distinction between need and requirement, so that a great deal of requirement information on decision support systems and information resources is also included below.

1. Intelligent Transportation Systems (ITS) Projects, USDOT, 1996-98.

Projects mentioning weather-information applications are found in the annual volumes, and are used to infer the needs served. It is likely that many studies and projects (e.g., the Early Deployment Program studies, traffic management center and ATIS deployments) consider weather information as part of ITS, but this would not be revealed unless weather was a special emphasis. A table was created that categorized types of projects from the project listings and inferred the weather information needs of the project types:

Table A1.1: ITS Projects and Implied Weather Information Needs

ITS Project Type	Implied Weather Information Needs
Traffic models for ITS analysis	Archival scenarios of weather, road surface conditions and traffic that enable statistical characterization of weather events amenable to ITS (ATIS and ATMS approaches) and evaluation of traffic flow benefits to improved maintenance.
Adaptive signal control system and ramp metering development	Archival scenarios of weather and traffic dynamics at signals relative to surface level of service (LOS) to design adaptive signal algorithms. Measurement of current surface LOS as input to algorithms.
Human factors in ATMS design	Effective presentation of weather information in decision support systems.
Integration of traffic operations and traffic data collection.	Collection of weather and road surface attributes and at locations most relevant to traffic control and maintenance.
Traffic surveillance and detection technology and operational tests	Integrated sensors that provide road condition, traffic and weather information.

Transportation management center interjurisdictional integration, and ITS standards	Sharing of information, including road weather information and coordination of weather-related decisions.
ATIS planning and operational tests	Traveler information including weather, weather-related road conditions and weather-related status of destination activities: route-organized, area-organized and itinerary-organized; nationally integrated; sub-hour to multi-week planning horizons.
ATMS planning and operational tests	Traffic management and maintenance information including weather and weather-related road conditions: infrastructure-facility organized and management jurisdiction-area organized; sub-hour to annual planning horizons.
Corridor planning and operational tests	Integrated traffic, weather and road condition instrumentation; immediate warning and other ATIS horizons; link-specific information; multiple information dissemination systems (roadside DMS, HAR, broadcast radio, cellular and other networked radio, Internet).
CVO planning and operational tests	Weather and weather-related road condition information for safety equipage and itinerary planning; multi-day horizons; probabilistic information for risk assessment of alternatives.
APTS planning and operational tests	Weather and weather-related road condition information for safety equipage, dispatching and customer information; sub-hour and multi-hour horizons; organized by service route and customer O-D areas.
Incident and emergency/disaster management planning and operational tests	Weather and weather-related road condition information for response dispatching and navigation; evacuation timing and routing; facility damage inference; HAZMAT spill and plume dispersion; sub-hour to multi-hour horizons; organized by route and incident areas.
AVCSS and AHS research and operational tests	Weather-related road conditions (surface LOS) as input to control systems.
Accident and driver performance database analysis/countermeasure actions analysis	Relation of weather-related conditions to safety hazards and delivery of credible driver warnings.
Vehicle-based lane detection	Lane-keeping when roadway obscured by weather conditions (visibility and road surface).
Vehicle feedback cues and driver performance	Additional ITS information needed to augment immediate driver perceptions for vehicle safety. Minimize interference between driving activities and onboard information systems.
ITS benefits assessment	Archival weather and transportation system scenarios for analyzing impacts of weather on system performance, and sensitivity outcomes to levels of weather information.
ITS architecture and mainstreaming	Adequate structure of weather information flows for ensuring appropriate inclusion in ITS planning and deployment

2. Needs from FHWA Workshop: Weather Information for Surface Transportation, The FHWA Weather Team, May 15, 1998

The Weather Team's two-day Workshop, held in June of 1997, gathered transportation and meteorological experts and practitioners. The list of needs falls into two broad categories: those concerning "the system" itself, and those concerning programmatic coordination. The system needs were further grouped into three subcategories. The first subcategory addresses components of the decision thread, and is heavy on the weather information resource compared to downstream components. Then comes system integration, in terms of sharing resources, creating an infrastructure and an architectural/standards framework for open systems. Third are needs for general system attributes that will support and enhance the system. The programmatic category concerns support for the system by public and private agencies, and coordination between those agencies. The table below gives these grouped needs.

Table A1.2: Needs from the May 1998 FHWA Workshop

Table 3: Weather Information for Surface Transportation--Needs
1. Decision Support and Coordination System
1.1 System Components (Decision Process Thread)
Improved observations —more fixed sites —mobile probes —communications to NWS —siting standards —quality, precision
Observation accessibility —sharing of local observations —assimilation and quality control of consolidated observations
Improved forecast quality —surface/subsurface —above surface —largescale (initializations, boundary conditions) —specialized, localized
Improved analysis (surface transportation attributes)
Sufficient decision support —selective access to all relevant databases —appropriate fusion of databases —tailored to decision —tailored to human factors —better use of decision science (uncertainty)

	Decision support effectiveness —dissemination of information to users —response effectiveness —resource control
	Evaluative feedback (Best Mgt. Practices)
1.2 System Integration	
	Integration of systems: —wide areas —inter-jurisdiction —inter agency (inter-modal) —multiple functions (maintenance, management, traveler information)
	ITS architecture conformity
	Better use of existing resources (communications, probes, etc.)
	Appropriate standards for open system —NTCIP/ESS —other NTCIP —other standards
	Culture change: organizational, informational
1.3 System Support and Enhancement	
	Operational Concept /Best Management Practices
	ITS architecture requirements
	Operational assessment with payoffs (what customer wants/needs/will use)
	Reliable, maintainable, available equip.
	Deployment of existing technology
	Culture Change: —General knowledge base —Reduced institutional obstacles to change, to informed decisions, to effective decisions
	Training, trained staff (resources and education)
2. Program Support and Coordination	
	NWS/Weather Forecast Office understanding of surface transportation needs
	Public-private role allocation —Responsibility —Opportunity
	Point of contact for localities to federal agencies, especially NOAA, DOD
	Support the NWS (adequate funding, staffing)
	Federal deployment support funding and procedures
	Point of contact in USDOT to OFCM, and to weather-related standards
	Private sector support funding: Partnerships

3. Needs from Rural ITS Research: Rural ITS User Needs, SAIC, May 26, 1999

The rural ITS program of the USDOT ITS Joint Program Office (JPO) has contracted with SAIC for research support. SAIC is formulating needs and ITS requirements along several development tracks, one of which is surface transportation weather information.

Culminating earlier needs surveys, SAIC conducted a stakeholder workshop on 4/18/99 to review and augment the V1.0 baseline rural ITS needs list that had been compiled from previous stakeholder input to the rural ITS program. Some useful observations made in the weather development track include:

- Some rural areas include such extreme differences in terrain and variability of weather within a single corridor, even within the same time frame.

- Weather-related crashes and delays represent a chronic problem for some rural areas prone to abrupt changes in conditions, terrain induced variability, and even seasonal occurrences such as spring and summer rainstorms creating flash flood conditions.

- Steep mountain grades combined with icy conditions present significant problems for commercial vehicle operators (as well as other travelers).

- Long response times of emergency services in [severe weather] conditions delay vitally needed medical care, and further exacerbate travel delays due to secondary incidents.

- ITS user needs for Weather information in rural areas involve gathering, processing and dissemination and fall into the following five general categories: 1) Advisory Information; 2) System Operational Effectiveness; 3) En-Route Services Information; 4) Leveraging Weather Information to Cost Containment, Profitability, and Safe Operations/Travel; 5) Data Sharing.

- There are distinctly different domains of weather information, including: climatology, observations, and forecasts of the atmosphere, and of pavement/ground conditions.

- Tailoring of weather information for specific users is at least regionalized or presented at local scales, which are defined climatologically.

- Successful use of weather information to optimize decision making depends on education of users relative to meteorology and diagnostic and forecasting capabilities, and of weather information providers relative to specific user requirements.

- Evaluation of forecast accuracy, and conditioning of forecasts such as by assignment of probability, are complex issues that need attention in operational environments.

In addition to the track devoted to weather information, weather was mentioned in a number of the other development tracks. All tracks ended up organizing needs according to similar functional categories. The table below merges weather needs from the other tracks into the organized list from the weather track (entries edited from source text).

Table A1.3: Weather Information Needs from the Rural ITS Needs Workshop

Advisory Information	
	Information regarding roadway and bridge surface conditions and timing that could affect travel conditions and operating speeds in the area (e.g., snow, icing, standing water, etc.)
	Information regarding weather conditions and timing that could affect travel conditions in the area (e.g., fog, freezing precipitation, thunderstorms, snow, tornadoes, visibility, etc.)
	Education of weather information users and providers re: the effects of weather on travel improve the outcome of decisions for weather-impacted activities.
Emergency Services (including emergency response team and emergency operations centers, victims, responders, trauma centers, analysts)	
	Forecasts for short term planning and observations of current weather to determine the maximum safe speed and routing available to responders, duration of closures, and mode choice. Surface and air responses have differing requirements.
	All scales of information required, temporal and spatial—historical, prospective, short-term forecast, current conditions, from synoptic (winter storm, for example) to meso-scale (thunderstorm). There is a moving domain of interest, starting with large area during early planning, forecasts for each geographical and functional areas of interest, small areas for near-term and instant case. Weather information detail varies.
	Crash Information (Data, Voice) – Automatic or manual distress signal system to disseminate traveler vehicle location and crash characteristics needed by emergency services. Required information includes: ... information on local weather conditions to determine wind direction/speed for HAZMAT information.
Tourism/Traveler	
	Some parameters of interest, forecast and observed, include: road conditions, wind speed and direction, visibility, hazardous and severe weather.
	General weather conditions for tourist enjoyment, regional and national scale depending on trip length.
	Road conditions deriving from weather effects on terrain, such as falling rock, mud and rock slides, avalanches.
	Travelers advisory usually has a short horizon for trips. Combine weather, road, and traffic information to provide travel information. Formats should be simple for lay-travelers, and focused on their route of travel. Weather information may be most useful when embedded in broader indicators such as Level of Service (LOS).

	There is a subtle conflict between the desire of recreation/destination operators to have weather portrayed in the most attractive light, and the need of tourists/travelers for honest information.
Traffic Management (Same as previous two tracks as well as the following:)	
	Weather effects on crew and staff scheduling
	Forecast and observed weather impacts on traffic flow.
	Seasonal delay information for systems designed to manage delays associated with specific seasonal effects such as flooding of certain areas in the spring or road and bridge icing during the winter (e.g. portable traffic management systems).
	Inputs to drafting of interagency agreements; e.g. permissible alternate routes necessitated by weather variations, and what, when, where and severity effects on traffic management actions.
	Duration and spatial extent of weather event; effect on designation of alternate routing.
	Weather observations and forecasts as input to traffic models (climatological distributions of conditions)
Transit and Mobility (much like Traffic Management track, also:)	
	Forecasts and observations focused on routes of particular importance. (Fixed route service reduces alternate routing and schedule flexibility.)
	Automatic Vehicle Location (AVL) data in combination with adverse weather information to provide display in dispatch and support safety-related decisions.
	Pre-Trip Traveler Information regarding transit routes, schedules, fares, and traffic conditions related to weather and provided through various media. Both real-time and static information are needed. Information to serve itinerary planning for regional trip making (using multiple modes/systems), information on intermodal connections; and notification of vehicle status and/or arrival time.
	Storm effects on roadway, rail, and pedestrian needs (passengers approaching, waiting, loading, unloading/departing).
	Thermal effects on trackage; icing on third-rail supplies.
	Snowfall rate, accumulation, drifting.
	Rain and hydrology, flash flooding and scouring.
Crash Prevention	
	Rural ITS User Needs identified for Crash Prevention and Security are broken-down into nine (9) categories including Roadway/Weather Information Systems (RWIS) defined to include elements to monitor and detect weather conditions that affect driver safety [e.g., visibility (snow/fog/sand), slippery roadway conditions (ice/snow/water), etc.).

	Road Surface Dynamic Warning [Variable Speed Limit (VSL)] – Systems designed to monitor and detect changes in roadway surface conditions affecting drivability. These systems would alert drivers of conditions and actuate system designed to adjust posted (electronic) speed limits to speed consistent with roadway condition.
	Speed Enforcement of Unsafe Driving Conditions – System designed to enhance law enforcement's ability to effectively identify and enforce unsafe driving conditions and driver behavior (e.g., speeding, weaving, etc,).
	Road and bridge surface conditions, and their effects on speed.
	Visibility.
	Spot warning.
	Operator education regarding the effects of weather on crash occurrence.
Operations and Maintenance	
	Roadway Surface and Atmospheric Conditions – Systems to monitor and detect changes in roadway surface conditions and other weather and atmospheric conditions affecting drivability, and to alert agencies of such changes. Conditions to be monitored would include ice, precipitation, fog, wind, blowing dust, and potentially air quality. Roadway surface condition information should also include a determination of coefficient of friction. Could also actuate systems to advise or warn drivers of these conditions.
	Winter Weather Maintenance – Systems to enhance the efficiency of pre-treatment and plowing operations, such as providing up-to-date information on weather and roadway surface conditions, location of nearest maintenance vehicle, time of last treatment or plowing per segment, or type of treatment or chemicals applied. Should also include systems on-board the maintenance vehicles that provide vehicle location, the ability for automated environmental recording, and automated recording of operational data (e.g., spreader on/off).
	Winter Weather Maintenance Safety – Systems installed on-board snow plows and other winter maintenance vehicles to assist the operator in lane following and detecting obstructions.
	Forecasts of conditions likely to produce avalanches, mudslides.
	Weather to affect work zone scheduling, material and its delivery, constructability, equipment.
	Climatology for planning, forecasts for scheduling, observations for reactive changes.
	Effects on facilities: power supply (lightning), chemical storage, resource protection.
System Operational Effectiveness	
	Weather forecast and other systems providing appropriate information regarding weather conditions and timing which could potentially affect transportation system operations; and transportation user safety and efficiency.

	Weather information requirements should be defined by each agency's (user) LOS standards. LOS usually depends on functional classification of roadways.
	Information gaps need to be filled to get sufficient observations both for diagnostic and forecast meteorology, and for operational use; and tailoring and synergistic (decision maker and meteorologist) integration are important.
	Cooperative agreements are needed to provide weather information for long and short range planning support resource management.
	Dissemination formats must have the user in mind.
	Forecast weather/solar effects on communications (e.g., microwave, high frequency).
En-Route Services Information	
	Very small scale weather impacts, spot conditions, affecting driving safety and travel time; for traveler's intended route and alternates.
	Current and arrival time destination weather conditions.
	Observations and forecasts to support stop and restart "what if" evaluations.
	Shelters/Red Cross (Weather) – Determine location and availability of sites designated as shelters during/following natural disasters such as flooding and other emergency events within predefined area or based on vehicle location. Lead time for determining when to activate shelters for emergencies.
	Current and forecast temperature and humidity for managing livestock stresses during travel.
	Consistency of language, format, and accessing of weather information across political boundaries.
Leveraging Weather Information to Cost containment, Profitability and Safe Operations/Travel	
	Weather Information Leveraging – Provide weather impact information on predetermined thresholds affecting cost and safety, with dissemination methods and formats tailored to various transportation users/stakeholders. Includes determining availability of suitable weather products and services, and/or taking actions to make them available.
	Corridor orientation, especially for very long trips, to facilitate route selection/optimization.
	Climatology to minimize vulnerability to flooding, pavement deterioration, avalanche, etc. Also should optimize facilities placement.
	Weather forecasts for "just in time" and stocking logistical practices.
	Descriptive weather information to support economic development.
Data Sharing	

	Support to weather analysis and prediction for surface transportation: Systems to enhance and share weather and pavement condition historical records and current observations from multiple sources to support accurate and definitive weather forecasts for surface transportation.
	Identify any need to archive surface transportation generated weather data, and its value in the marketplace.

5. Foretell User Survey: Briefing materials prepared by Mitretek, 9/25/98, based on Foretell System design Concept, Castle Rock Services, Inc., March 1998.

Foretell™ is the first operational test sponsored by the FHWA Weather Team. As part of their system requirements process, Castle Rock Services (CRS) surveyed its constituents and obtained needs that go far toward system requirements. The quantifications given are not definitive but will be enhanced in the further requirements analysis. Lead times, areas covered and resolution will require technical and economic tradeoffs with accuracy/precision (of attribute, time and location), false alarm rate (FAR) and probability of detection (POD). These require specific determination for each type of decision support. Also, the requirements should include reliability/probability specifications for risk decisions. The table below was organized by Mitretek as part of this task.

Table A1.4: Foretell-based User Needs/Requirements

Decision Maker/ Type of Decision	Weather Information Needs	Decision Support Requirements
Highway Maintenance District Supervisors		
P Equipment/stores planning P Crew scheduling P Road treatment for icing P Snow removal P Scheduled road work P Incident response	*Surface temperature *Surface dew point *Surface relative humidity *Precipitation rate, amount, type *Surface winds *Cloud cover *Severe storm watches/warnings	— annual climatic variations: for the region, a year ahead, especially precipitation amounts — annual roadbed thaw and freeze dates: 2 week lead — road segments that will form surface ice: 6 hour lead and updates — road segment snow coverage: 12 hr. lead and updates with duration and rates — roadbed segment temperature below freezing for pavement laying: 12 hr. lead — area road/air temperature limit (high and low) exceedence for work crews: 3 mos. planning and 12 hr. operational lead — severe local storm winds and precipitation track: 1 hr. warning and updates, to stream-shed or <5 Km resolution.
Highway Traffic Managers		
P Close route P Issue advisory P Traffic control P Manage incident	*Surface temperature *Surface dew point *Surface relative humidity *Visibility *Precipitation rate, amount, type *Surface winds *Cloud cover *Severe storm watches/warnings	— onset of unsafe visibility, surface icing or severe local storm, by route segment: 1 hr. warning, 15 min. lead for closure, 5 min. lead for advisory — regional (including interstate) network pavement level of service (LOS), by major highway route segment: 24 hour rolling horizon with updates down to 1 hr. — avalanche danger at critical passes: continuous watch with 6 hr. lead and update to 1 hr.

Public Safety, Emergency Managers, National Response Center		
P Elevate readiness P Response vehicle selection P Evacuation P Search and rescue P HAZMAT response P Fire modeling P Other incident response P Medical service	*Surface temperature *Convection stability *Visibility *Precipitation rate, amount, type *Surface winds *Severe storm watches/warnings	— landslide, avalanche and flash flood warning by watershed: 2 hour warning, 1 hr. high probability warning and ex-post detection. — basin flood warning: 3 mos. climatic warning, 12 hour crest warning. — hurricane track and severity: 24 hour alert, 12 hr. high probability track for evacuation. — severe local storm watch and warning: 2 hr. watch, 1 hr. warning with 30 min update and track to ~5 km. — general regional search and survival conditions of visibility, winds, temperature: 12 hour forecast. — HAZMAT plume transport: winds, convection and precipitation to allow tracking over 6 hour horizon, to within 45 degree sector and 1 km range. — HAZMAT spill runoff factors: site-specific precipitation over 6 hour horizon. — fire spread track and extent: winds, ground condition and precipitation to allow tracking over 6 hour horizon, to within 45 degree sector and 1 km range.
Planners of Transportation and Events		
P Schedule events P Design facilities P Manage pollution episodes	*Surface temperature *Convection stability *Precipitation rate, amount, type *Surface winds *Cloud cover *Severe storm watches/warnings	— precipitation, extreme temperatures and winds that would preclude outdoor events: climatic averages, 1 week forecast and reliable update at 24 hrs. — climatic factors relevant to facility location or highway design: seasonal frequency and duration of visibility problems, surface runoff, flood plains, mudslides, severe winds, temperature and wind roses. — air pollution (CO, Ozone, PM) exceedence probability: forecast for 5 AM to 7 PM (local) period

Commuter Travelers		
P Pre-trip route/mode choice P En route driving route diversion	*Surface temperature *Visibility *Precipitation rate, amount, type *Surface winds *Severe storm watches/warnings	— pavement and traffic LOS, and transit on-time performance, by personalized route: delivered 1 hr. before AM and PM departure. — pavement and traffic LOS, and other hazardous conditions, for area road segments and selectable by vehicle route: continuous updates with <10 min. lag. — snow chain/tire, block heater/anti freeze alert: 24 hr. warning of sudden temperature drop.
Pleasure/Long Distance Travelers		
P Pre-trip itinerary planning P En route diversion and stopover planning	*Surface temperature *Visibility *Precipitation rate, amount, type *Surface winds *Severe storm watches/warnings	— pavement and traffic LOS, and synoptic weather conditions by selectable itinerary: up to 7 day horizon after trip start and delivered 7 days before trip start and rolling updates. — pavement and traffic LOS, and other hazardous conditions, for regional road segments (including multi-state) and selectable by vehicle route: continuous current updates with <10 min. lag and 1-day outlooks with <30 min update lag.
School District Supervisors		
P AM close/open P Midday dismissal P School bus equipage	*Surface temperature *Precipitation rate, amount, type *Severe storm watches/warnings	— forecast of severe storm, precipitation or temperature extremes, that would lead to closure/dismissal for district area, with confidence ratings: for 6 AM to 4 PM (local) delivered at 5 AM, and updates throughout day. — snow chain/tire, block heater/anti freeze alert: 24 hr. warning of sudden temperature drop.
Local Transit Schedulers and Dispatchers		

P Fleet/track equipment P Runcutting P Route/schedule adjustment	*Surface temperature *Precipitation rate, amount, type *Severe storm watches/warnings	— pavement and traffic LOS, and other hazardous conditions, for area road segments and selectable by vehicle route: continuous updates with <10 min. lag. — climatic and synoptic conditions affecting running time for month: update at runcutting cycle. — track plowing, 3rd rail heating alert: 12 hour warning and updates of snow accumulation. — snow chain/tire, block heater/anti freeze alert: 24 hr. warning of sudden temperature drop.
Commercial Vehicle Operators		
P Fleet equipment P Haul assignment P Route/schedule dispatching P En route diversion and stopover planning	*Surface temperature *Visibility *Precipitation rate, amount, type *Surface winds *Severe storm watches/warnings	— pavement and traffic LOS, and synoptic weather conditions by selectable itinerary: up to 7 day horizon after trip start and delivered 7 days before trip start and rolling updates. — pavement and traffic LOS, and other hazardous conditions, for regional road segments (including multi-state) and selectable by vehicle route: continuous current updates with <10 min. lag and 1-day outlooks with <30 min update lag. — snow chain/tire, block heater/anti freeze alert: 24 hr. warning of sudden temperature drop.

6. Weather Requirements in the National ITS Architecture

Source: http://www.odetics.com/itsarch/
Hypertext Architecture Version 2.2 generation date 6/1/99 from the
Logical Architecture dated 05/04/99 and the
Physical Architecture dated 5/28/99

The National ITS Architecture was derived based on user needs. The link between needs and the ITS are a set of user services, hierarchically organized under a set of user-service bundles. Needs are documented for user services, and result in user service requirements allocated to the ITS. There is no “weather” user service, but rather weather information serves the decisions included in various ITS user services.

An attempt was made to map weather information needs to the service bundles and their subsidiary user services from the ITS architecture[1]. [Weather Information for Surface Transportation, The FHWA Weather Team, May 15, 1998]:

[1] The ITS architecture, most recent version, can be found at www.odetics.com. Since the original needs analysis, the ADUS User Service has been added. Needs associated with ADUS are included in data sharing and archiving needs elsewhere.

Table A1.5: Weather Information Needs of the ITS User Services

User Services Bundles	User Services	Weather Information Needs
Travel and Transportation Management	· En-Route Driver Information · Route Guidance · Traveler Services Information · Traffic Control · Incident Management · Emissions Testing and Mitigation · Demand Management and Operations · Pre-trip Travel Information · Ride Matching and Reservation · Highway Rail Intersection	··Itinerary route weather and pavement surface condition ··Weather for destination services (e.g., skiing) ··Pavement LOS relative to traffic LOS ··Hazmat and pollutant runoff and plume conditions ··Ice, snow and water coverage of routes for treatment ··Other hazardous-travel weather conditions
Public Transportation Operations	· Public Transportation Management · En-Route Transit Information · Personalized Public Transit · Public Travel Security	··Climatic and storm vehicle-equipage ··Ice, snow and water coverage of routes for dispatching ··Ice, snow and water coverage of tracks for treatment ··Hazardous weather for vehicle operation or waiting passengers
Electronic Payment	· Electronic Payment Services	··Severe weather that may affect toll system facilities
Commercial Vehicle Operations	· Commercial Vehicle Electronic Clearance · Automated Roadside Safety Inspection · On-board Safety Monitoring · Commercial Vehicle Administration Processes · Hazardous Materials Incident Response · Freight Mobility	··Itinerary route weather and pavement surface condition for dispatching ··Hazmat and pollutant runoff and plume conditions ··Severe weather that may affect toll automated roadside facilities
Emergency Management	· Emergency Notification and Personal Security · Emergency Vehicle Management	··Itinerary route weather and pavement surface condition for dispatching ··Hazmat and pollutant runoff and plume conditions ··Severe weather that may prompt search and rescue activity
Advanced Vehicle Control and Safety Systems	· Longitudinal Collision Avoidance · Lateral Collision Avoidance · Intersection Collision Avoidance · Vision Enhancement for Crash	··Route weather and pavement surface condition for automated highway parameter setting ··Micro-weather and pavement

	Avoidance · Safety Readiness · Pre-Crash Restraint Deployment · Automated Highway System	sensing for vehicle control and probe transmission ·· Severe weather that may affect automated systems

The user service requirements can be found in the architecture and traced to process specifications (pspec) attached to the data flow diagram (dfd) processes (i.e., decisions) of the logical architecture. The traceability matrices of the architecture allow searching for weather and related terms to identify how weather information enters the user service requirements, pspecs and data flows. A search was conducted with the following search terms:

- Weather: identifying weather information generally in the users services and pspecs. The current and predicted weather information flows derive primarily from the Weather Service terminator.

- Environmental: this locates requirements for environmental data within the user services and the pspec of "process environmental sensor data" within the roadway subsystem.

- Snow: revealed the onboard sensor pspec of Process Vehicle On-board Data and its "smart probe" function under the vehicle subsystem.

The users service requirements found by this search are listed below:

1.0 TRAVEL AND TRAFFIC MANAGEMENT		
	1.1 PRE-TRIP TRAVEL INFORMATION (PTTI)	
		1.1.2.1.8 Real-time information provided by PTTI shall include the current weather situation.
		1.1.3.2.10 PTTI shall provide the capability for users to specify their preferred weather conditions.
	1.2 EN-ROUTE DRIVER INFORMATION	
		1.2.3.2.2.1 The customized warnings function shall provide the capability to control the contents of warning messages to the extant environmental conditions.
		1.2.3.2.3 The in-vehicle signing function shall provide the capability to utilize data from roadside environmental sensors as inputs to warning messages.
	1.7 INCIDENT MANAGEMENT	

		1.7.1.1.1 The incident identification function shall use information from the following types of sources, where available, to identify *predicted* incidents: 1.7.1.1.1(b) Environmental sensors. 1.7.1.1.1(e) Weather information sources. 1.7.1.2.1 The incident identification function shall use information from the following types of sources, where available, to identify *existing* incidents: 1.7.1.2.1(b) Environmental sensors. 1.7.1.2.1(e) Weather information sources.

The process specification (pspec) descriptions were searched in the traceability matrix of Appendix H: Subsystem and Equipment Package Functional Summary. This located the following entries that describe the pspec associated with an equipment package (a pspec may belong to more than one equipment package, but duplicates are not indicated below). Emphasis is added for the weather entries:

Calculate Vehicle Route (P-Spec 6.6.2.1)
Overview: This process shall calculate trip planning and real-time dynamic guidance routes for all types of vehicles. The route data provided by the process in response to requests from vehicles using infrastructure based in-vehicle guidance shall only contain data necessary for the vehicle to provide guidance (since the data is intended for use by an in-vehicle navigation unit). The route provided for trip planning purposes shall contain data in a form which can be presented to a user via display (or alternatively in audio form). The process shall select the route according to the data included in the route request. Data provided by the requesting process includes preferences and constraints. The process shall have the capability of using ***current and/or predicted conditions of the road network*** in route calculation. The process shall have the capability of including additional factors such as ***current or predicted weather*** in the calculation of route. If the process cannot find the data it needs in the route_segment_details_data store, it shall request the process responsible for providing route calculation data to obtain it from the appropriate source. The process shall have the capability of outputting routes for special priority vehicles to the Manage Traffic function so that signal preemption could be provided for the special priority vehicle. The process shall send details of routes for commercial vehicles with hazardous or unusual loads to the Manage Incidents function for monitoring (as a potential, or a predicted incident).

Collect and Update Traveler Information (P-Spec 6.5.1)
Overview: This process shall collect and update data about incidents, road construction, ***weather***, events and yellow pages data. This data shall be obtained by the process from other ITS functions and from outside sources such as the weather service, yellow pages service providers and the media. The process shall load the data into a local store for use by the process that provides yellow pages information and reservations.

Evaluate System (P-Spec 8.2.4)
Overview: This process shall be responsible for the evaluation of the performance of the network of roads and freeways served by the local ITS function. This evaluation shall take into account any factors that may affect performance such as, ***weather***, travel demand, the desire to reduce emissions, transit services, proportion of guided and non-guided vehicles, historic performance,
etc. From the results produced by the process it shall be possible to deduce the effects that any changes to the network have had on its performance in terms of its ability to move people and goods and the efficiency with which this is achieved. The process shall be driven by the input of evaluation parameters received from the transportation planner via the interface processes. The same processes shall be supplied with the results of the evaluation.

Simulate System (P-Spec 8.2.5)
Overview: This process shall be responsible for providing a simulation of the way in which the road and freeway network served by the local ITS functions will operate in terms of the traffic volumes, delays, etc. experienced. The simulation performed by the process shall take into account factors which may affect system performance such as ***weather***, travel demand, the desire to reduce emissions, transit services, proportion of guided and non-guided vehicles, historic performance, etc. The process shall be driven by the input of simulation parameters received from the transportation planner via the interface processes. The same processes shall be supplied with the results of the simulation.

Provide Traffic Operations Personnel Traffic Data Interface (P-Spec 1.1.4.2)
Overview: This process shall provide the interface through which traffic operations personnel can obtain access to the data stored by other processes in the Provide Traffic Surveillance facility of the Manage Traffic function, and set up the parameters that govern the data that is available to non-traffic operations people via a separate process to the media operator. This stored data shall comprise ***current and long term (historic) data*** on traffic conditions, ***weather*** conditions and roadside equipment activity, plus prediction estimates of traffic conditions. The data shall apply to some or all of the road and freeway network served by the specific instance of the Manage Traffic function. Where appropriate and/or requested by the traffic operations personnel, the process shall provide the ***data output in the form of an overlay onto a map*** of the relevant part(s) of the road and freeway network served by the instance of the function. The process shall obtain the map from a local data store, which it shall enable the traffic operations personnel to update as and when required.

Rail Operations Coordination Equipment Package consists of:
Generate Predictive Traffic Model (P-Spec 1.1.3)
Overview: This process shall be responsible for continually producing and updating a predictive model of the traffic flow conditions in the road or freeway network served by the Manage Traffic function that an instance of this process is allocated to. The prediction shall be based on current surveillance, historic traffic conditions and surveillance, current and predicted incidents, current traffic control strategy, data received from other Traffic Management Subsystems (TMS's) serving other geographic and/or jurisdictional areas, and ***current and predicted weather conditions***. The predictive model of traffic

flow produced by this process shall be used by processes in the Manage Traffic function and other ITS functions.

TMC Road Weather Monitoring Equipment Package consists of:
Process Traffic Data for Storage (P-Spec 1.1.2.1)
Overview: This process shall receive data from other processes and store the data into the long term and current data stores. The data shall comprise ***sensor data, both smoothed and unsmoothed***: ***processed sensor surveillance data, data sent to control indicators (output devices e.g. intersection controllers, pedestrian controllers, variable message signs, ramp metering equipment)***, parking lot management data and other street equipment, the status data received from the indicators, plus current traffic conditions, predicted incidents, current incidents, parking lot states, ramp states, link travel times, ***road conditions provided by vehicle probes***, and selected traffic control strategy. The data stored by the process in the current data store shall be the values collected over a relatively short period of time. The data stored in the long term data store shall be retained for a longer period. The ***data retained in the long term data store may be aggregated*** so as to reduce the storage requirements for long historical records, the amount of aggregation to be an implementation decision.

Mentions of environmental sensor were searched in the traceability matrix of Appendix H: Subsystem and Equipment Package Functional Summary, and located in the following entries:

Roadway Environmental Monitoring Equipment Package consists of:
Process Environmental Sensor Data (P-Spec 1.1.1.3)
Overview: This process shall be responsible for collecting data obtained from environmental sensors. Where any of the data is provided in analog form, the process shall be responsible for converting it into digital form and calibrating. The converted data shall be sent to other processes for distribution, further analysis and storage.

Process Vehicle On-board Data (P-Spec 3.1.3)
Overview: This process shall be responsible for processing data received as input to sensors located on-board a vehicle. The process shall continuously analyze these inputs and produce data from which safety and/or position warnings and actions can be produced by another process. It shall also analyze the data to check for ***hazardous roadside conditions such as flooding, ice, snow, etc***. and if detected shall output this data to processes in the Manage Traffic function.

12.2 Needs Tabulations

The following table shows needs for all decision makers related to surface transportation weather. The needs are organized by three scale categories and listed under decision-maker types. The needs are stated as decisions to be made that depend on weather information. The need *for* information is the subject of the operational analysis for each decision maker.

		Micro-Scale	Meso/Synoptic	Synoptic/Climatic
D M #	**Need#**	**Warning**	**Operational**	**Planning**
1.0	Infrastructure Operators			
1.1	Highway maintainer (winter)			
	1.1	control spreader application		
	1.2	control plow		
	1.3	control static (bridge) deicer		
	1.4	observe/report		
	1.5	navigate spreader/plow truck		
	2.1		detect/monitor weather event	
	2.2		schedule crews (split shifts)	
	2.3		prepare equipment	
	2.4		mix/load/replenish expendables	
	2.5		dispatch crews	
	2.6		program treatment control	
	2.7		repair/adjust equipment	
	2.8		coordinate (e.g., traffic mgt.)	
	2.9		request resource aid	
	2.10		dispatch damage repair	
	3.1			devise response plan
	3.2			hire staff
	3.3			train staff
	3.4			buy equipment/services
	3.5			stock stores
	3.6			budget
	3.7			schedule seasonal tasks
	3.8			calibrate treatment controls
1.2	Highway maintainer (other)			
	1.1	control application		
	1.2	cease/restart work		
	1.3	operate pump		
	2.1		schedule crews	
	2.2		prepare equipment	
	2.3		dispatch crews	
	2.4		request aid	
	2.5		repair damage	

	3.1			hire crews
	3.2			buy equipment
	3.3			stock stores
	3.4			budget
	3.5			schedule seasonal tasks
1.3	Traffic manager			
	1.1	activate controls (manual)		
	1.2	set control parameters		
	1.3	activate warning (manual)		
	2.1		predict traffic	
	2.2		prepare route closure	
	2.3		prepare route restriction	
	2.4		prepare safety advisory	
	3.1			prepare route restriction
	3.2			predict traffic
	3.3			prepare travel advisory
1.4	Information system manager			
	1.1	control network		
	2.1		control network	
	3.1			specify network
	3.2			subscribe capacity
1.5	Traffic device controllers			
	1.1	activate controls		
	1.2	set control parameters		
	2.1		activate controls	
	2.2		set control parameters	
1.6	RWIS Maintainer			
	1.1	calibrate system		
	1.2	detect fault		
	2.1		calibrate system	
	2.2		detect fault	
	2.3		validate system	
	3.1			validate system
1.7	Rail maintainer			
	1.1	cease/restart work		
	2.1		schedule crews	
	2.2		prepare equipment	
	2.3		operate track facilities	
	2.4		dispatch crews	
	2.5		request aid	
	2.6		repair damage	
	3.1			hire crews
	3.2			locate crews
	3.3			buy equipment
	3.4			stock stores
	3.5			budget
	3.6			schedule seasonal tasks
1.8	Waterways operator			
	1.1	activate spillways		
	2.1		activate spillways	

	2.2		close/open waterway	
	2.3		advise traffic	
	3.1			activate spillways
	3.2			advise traffic
	3.3			predict traffic
2.0	Infrastructure Builder/Planner			
2.1	Transportation designer			
	3.1			specify design
	3.2			specify location
	3.3			specify materials
2.2	Transportation builder			
	1.1	cease/restart work		
	1.2	protect work		
	2.1		schedule crews	
	2.2		prepare equipment	
	2.3		dispatch crews	
	2.4		adjust materials	
	2.5		protect work	
	3.1			schedule projects
	3.2			hire crews
	3.3			order equipment & supplies
	3.4			budget and finance
	3.5			bid projects
2.3	Transportation planner			
	1.1	detect pollution event		
	2.1		tactical pollution mitigation	
	3.1			pollution conformity planning
	3.2			allocate land uses
	3.3			allocate transportation capacity
	3.4			program projects
	3.5			budget projects
2.4	Transportation evaluator			
	1.1	evaluate traffic flow		
	1.2	evaluate traffic safety		
	2.1		evaluate traffic delay	
	2.2		evaluate environmental impact	
	2.3		evaluate cost	
	2.4		evaluate opnl. effectiveness	
	3.1			evaluate environmental impact
	3.2			evaluate traffic safety
	3.3			evaluate cost
3.0	Information service provider			
	1.1	spot traveler warnings		
	1.2	disseminate weather warning		
	2.1		update traveler information	
	2.2		multimodal route selection	

	2.3		calculate vehicle route	
	3.1			update traveler information
	3.2			multimodal route selection
	3.3			calculate vehicle route
4.0	Fleet Operators			
4.1	Transit-fixed			
	2.1		service adjustment	
	2.2		equipment preparation	
	3.1			service routing
	3.2			service scheduling
	3.3			runcutting
	3.4			equipment purchase
	3.5			staff hiring
	3.6			budgeting
4.2	Transit-demand responsive			
	1.1	next stop update		
	2.1		dispatch service	
	2.2		advise customers	
	2.3		equipment preparation	
	3.1			fleet sizing
	3.2			runcutting
	3.3			equipment purchase
	3.4			staff hiring
	3.5			budgeting
4.3	School bus/district manager			
	2.1		close/open decision	
	2.2		equipment preparation	
	3.1			AM close/open decision
	3.2			equipment preparation
	3.3			scheduling
	3.4			staff hiring
	3.5			budgeting
4.4	Commercial fleet dispatcher			
	2.1		route/schedule short-haul	
	2.2		advise route/schedule change	
	2.3		advise customer of delivery	
	3.1			route/schedule long-haul
	3.2			assign hauls
	3.3			equipment purchase
	3.4			equipment preparation
	3.5			predict load limits
	3.6			protect loads
4.5	Railway dispatcher			
	1.1	stop train		
	2.1		route change	
	2.2		slow order	
	2.3		layover	
	2.4		advise customer of delivery	
	3.1			route/schedule train

	3.2			schedule crews
	3.3			assign hauls
	3.4			equipment purchase
	3.5			equipment preparation
4.6	Barge dispatcher			
	2.1		layover	
	2.2		advise customer of delivery	
	2.3		advise locks of arrival	
	3.1			schedule trips
	3.2			assign crews
	3.3			assign hauls
	3.4			prepare equipment
	3.5			predict tonnages
4.7	Military movement managers			
	2.1		route change	
	2.2		layover	
	2.3		advise port of arrival	
	3.1			schedule trips
	3.2			route convoys
	3.3			prepare equipment
	3.4			protect loads
	3.5			predict load limits
4.8	Hazardous/special cargo managers			
	1.1	halt trip		
	1.2	divert trip		
	1.3	advise emergency units		
	1.4	protect load		
	2.1		route	
	2.2		schedule	
	2.3		layover	
	2.4		advise emergency units	
	2.5		predict checkpoints	
	3.1			schedule trip
	3.2			route
	3.3			prepare equipment
	3.4			protect loads
	3.5			predict load limits
	3.6			advise emergency units
5.0	Vehicle operators			
5.1	Highway drivers			
	1.1	reduce speed		
	1.2	increase following distance		
	1.3	avoid obstacle		
	1.4	seek shelter		
	1.5	layover		
	1.6	activate vehicle equipment		
	2.1		prepare vehicle	
	2.2		replenish consumables	
	2.3		personal equipment	

	2.4		plan layover	
	3.1			purchase vehicle
	3.2			equip vehicle
	3.3			seasonally prepare vehicle
5.2	Vehicle control system			
	1.1	reduce speed		
	1.2	increase following distance		
	1.3	activate vehicle equipment		
	1.4	identify fault		
	1.5	output vehicle display		
	1.6	process onboard data		
5.3	Train engineers			
	1.1	reduce speed		
	1.2	layover		
	1.3	activate train equipment		
	2.1		personal equipment	
5.4	Barge and boat navigators			
	1.1	reduce speed		
	1.2	change heading		
	1.3	layover		
	1.4	activate equipment		
	2.1		personal equipment	
6.0	Travelers			
6.1	Traveler awaiters			
	1.1	mitigate meeting conditions		
	2.1		anticipate meeting	
	2.2		inquire trip status	
	2.3		request search	
	2.4		perform search	
	2.5		advise visitor preparation	
	3.1			request visit
	3.2			advise visitor preparation
6.2	Personal traveler/recreational			
	1.1	cancel stop		
	1.2	prepare for debarking		
	1.3	decide reembarking		
	1.4	protect POV		
	2.1		select trip mode	
	2.2		chain trip stops	
	2.3		select routes	
	2.4		revise routes	
	2.5		make schedule	
	2.6		revise schedule	
	2.7		arrange stop activities	
	2.8		revise stop reservations	
	2.9		cancel stops	
	2.10		pack gear	
	3.1			select trip mode

	3.2			chain trip stops
	3.3			select routes
	3.4			make schedule
	3.5			arrange stop activities
	3.6			cancel stops
	3.7			pack gear
6.3	Personal traveler/commuter			
	1.1	prepare for debarking		
	1.2	protect POV		
	2.1		select trip mode	
	2.2		chain trip stops	
	2.3		select routes	
	2.4		revise routes	
	2.5		select departure time	
	2.6		advise late arrival/absence	
	2.7		select personal equipment	
	2.8		plan alternate activity	
	3.1			advise late arrival/absence
	3.2			plan alternate activity
6.4	Personal traveler/business			
	1.1	prepare for debarking		
	1.2	protect POV		
	2.1		select trip mode	
	2.2		chain trip stops	
	2.3		select routes	
	2.4		revise routes	
	2.5		make schedule	
	2.6		revise schedule	
	2.7		arrange stop activities	
	2.8		revise stop reservations	
	2.9		cancel stops	
	2.10		advise awaiter	
	2.11		pack gear	
	3.1			select trip mode
	3.2			chain trip stops
	3.3			select routes
	3.4			make schedule
	3.5			arrange stop activities
	3.6			pack gear
6.5	Personal traveler/discretionary			
	1.1	cancel stop		
	1.2	prepare for debarking		
	1.3	decide reembarking		
	1.4	protect POV		
	2.1		select trip mode	
	2.2		chain trip stops	
	2.3		select routes	
	2.4		revise routes	
	2.5		make schedule	
	2.6		revise schedule	

	3.1			advanced activity planning
7.0	Incident/emergency response			
7.1	Emergency medical dispatcher (PSAP)			
	2.1		choose response unit(s)	
	2.2		route response unit(s)	
	2.3		advise arrival time	
	2.4		response preparation	
	2.5		advise casualty actions	
	2.6		preposition respondents	
	3.1			seasonal readiness
	3.2			respondent siting
	3.3			equipment purchase
	3.4			staff training
7.2	Public safety dispatcher			
	2.1		choose response unit(s)	
	2.2		route response unit(s)	
	2.3		advise arrival time	
	2.4		response preparation	
	2.5		preposition respondents	
	3.1			seasonal readiness
	3.2			respondent siting
	3.3			equipment purchase
	3.4			staff training
7.3	Infrastructure incident dispatcher			
	1.1	detect damaging event		
	2.1		choose response unit(s)	
	2.2		route response unit(s)	
	2.3		response preparation	
	2.4		preposition respondents	
	3.1			seasonal readiness
	3.2			respondent siting
	3.3			equipment purchase
	3.4			staff training
	3.5			materials purchase
7.4	Disaster evacuation manager			
	1.1	detect threatening event		
	1.2	determine threatened area		
	1.3	activate alarm		
	2.1		predict threatening event	
	2.2		predict threatened area	
	2.3		determine shelter sites	
	2.4		determine evacuation routes	
	2.5		supply shelter sites	
	2.6		position evacuation guides	
	2.7		issue evacuation order	
	3.1			seasonal readiness
	3.2			event readiness
	3.3			site stocks

	3.4			determine shelter sites
	3.5			supply shelter sites
	3.6			equipment purchase
	3.7			staff training
	3.8			stocks purchase
7.5	Disaster response manager			
	1.1	detect threatening event		
	1.2	determine threat response		
	1.3	request response		
	2.1		predict threat profile	
	2.2		determine response	
	2.3		schedule response	
	2.4		request response	
	2.5		prepare respondents	
	2.6		preposition respondents	
	3.1			water release
	3.2			seasonal readiness
	3.3			require mitigations
	3.4			site stocks
	3.5			equipment/crew contracting
	3.6			stocks purchase
7.6	Search and rescue manager			
	1.1	detect threatening event		
	1.2	choose search mode		
	1.3	estimate search area		
	1.4	request search		
	2.2		ready crews	
	2.3		ready equipment	
	3.1			seasonal readiness
	3.2			equipment purchase
	3.3			crew training
7.7	Insurer			
	2.1		predict loss	
	2.2		alert agents	
	3.1			predict loss
	3.2			promote mitigations
	3.4			actuarial estimation
8.0	Activity managers			
8.1	Special event planner			hire agents
	1.1	close event		
	2.1		schedule event	
	2.2		cancel event	
	2.3		shelter event	
	3.1			plan event
8.2	Recreation managers			
	1.1	close venue		
	1.2	secure facilities	close venue	
	2.1		secure facilities	
	2.2			build facilities

	3.1			hire staff
	3.2			budget fees and costs
	3.3			
8.3	Retail managers			
	1.1	shelter/secure stock		
	2.1		shelter/secure stock	
	2.2		display weather-related stock	
	3.1			order stock
	3.2			locate facilities
	3.3			design facilities
8.4	Production manager-industrial			
	1.1	stop/start work		
	1.2	shelter stock/secure facility		
	2.1		schedule shifts	
	2.2		schedule tasks	
	3.1			plan inventory
	3.2			plan production
	3.3			locate facilities
	3.4			design facilities
	3.5			buy equipment
	3.6			hire labor
8.5	Production manager-agricultural			
	1.1	stop/start harvest		
	1.2	shelter livestock		
	1.3	secure equipment		
	2.1		schedule harvest	
	2.2		protect crop	
	2.3		irrigate	
	2.4		schedule husbandry tasks	
	2.5		schedule crop treatment	
	2.6		schedule support tasks	
	3.1			buy seed and stock
	3.2			plan harvest and slaughter
	3.3			schedule planting
	3.4			contract for harvesting
	3.5			build facilities
	3.6			buy equipment
	3.7			hire labor
8.6	Brokerage and futures			
	2.1		offer commodity price	
	3.1			offer commodity price
	3.2			buy futures
	3.3			sell futures
	3.4			build inventory capacity
	3.5			sell inventory
8.7	Power system managers			
	1.1	reallocate transmission		
	2.1		allocate generation	
	2.2		allocate transmission	
	2.3		ready line crews	

	3.1			stock fuel
	3.2			schedule shutdowns
	3.3			invest in facilities
	3.4			promote conservation
	3.5			hire crews