Developing Surface Transportation Weather Requirements in the United States

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I Introduction

The critical role of road weather information as a tailored weather product for winter maintenance purposes was first demonstrated in the United States under the Strategic Highway Research Program in the late 1980's [Boselly, et al, 1993]. This information proved most valuable, even essential, to support anti-icing, though it also supported other maintenance activities. Through the 1990's, information systems and other technology applications expanded significantly in the transportation environment under the auspices of Intelligent Transportation Systems (ITS). These systems were built primarily to support traffic management and congestion relief, though the full scope of ITS supports 31 different services [USDOT, 1999]. These two elements – tailored road weather products and an extensive transportation technology infrastructure – constitute two key building blocks for the development of information systems that can alleviate the impacts of adverse weather upon the surface transportation system. These information systems go beyond those first developed for winter maintenance by meeting the weather information needs of all road users and operators.

The U.S. Department of Transportation, Federal Highway Administration (FHWA) formed the Weather Team in 1997 to explore improved surface transportation weather information systems. Out of these efforts, a white paper was produced that captured the vision of an improved transportation system due to reduced impacts of adverse weather [FHWA, 1998]. The paper also identified areas in need of further work. In 1999, the Weather and Winter Mobility program was formed within the FHWA, Office of Transportation Operations. This development formalized the FHWA commitment to surface transportation weather. The goals of this new program are to:

1. Develop weather information systems that meet the demands of all road users and operators,
2. Develop improved maintenance technologies for winter mobility, and
3. Develop traffic operations procedures under all weather threats.

There are a number of projects and related efforts taking place within the program, with one of the most critical being the documentation of surface transportation weather requirements. In the white paper it was determined that improving system performance required the improved support to the decision-making process. Better decisions beget better operations and improved outcomes. And in order to improve decision systems, it was necessary to determine the information needs of the decision makers. Once these needs are determined, system requirements can be developed. These requirements will meet two critical program needs: 1) they enable the meteorological community to modify their products to better meet the end users' needs, and 2) they serve as design elements for the next generation of weather decision support systems (dubbed the Weather Information for Surface Transportation Decision Support System (WIST-DSS)).

The FHWA contracted with Mitretek Systems, Inc., in mid-1999 to produce a guidance document called the Surface Transportation Weather Decision Support Requirements (STWDSR). The approach to this task includes analysis of highway-treatment operations scenarios in combination with weather-event scenarios to define information needs. Requirements definition will focus initially on winter highway maintenance, and will involve the stakeholder community of system users and developers. The STWDSR for winter highway maintenance is due for completion in mid-2000.

II The STWDSR Approach

The STWDSR starts with the distinction that needs are held by decision makers (whether human, or automatic controller), driven by goals for transportation system performance. Requirements are attributes allocated to systems that meet the needs. Therefore, requirements are validated ultimately by improvements in transportation system performance. The performance measures of interest include safety, mobility, productivity, and environmental quality. In the case of winter highway maintenance, these relate to prompter recovery of desired pavement levels of service (LOS), minimization of maintenance costs, and minimization of chemical applications. This obviously implies a tradeoff and the biggest challenge is to determine how weather information relates to changes in the outcomes.

The STWDSR is merging a needs analysis step with a process that is indicated by the contents of an Operational Concept Description (OCD) document. The OCD is specified as part of the system engineering process in MIL-STD-498, and its successors such as [EIA/IEEE, 1999]. The core content of the OCD is: 1) description of the current system, 2) justification for changes (via needs analysis), 3) concept for a new system, and 4) operational scenarios (descriptions of how the new system would work). The essential point is to let needs define the requirements, as opposed to assuming system-solutions.

The process from needs analysis to requirements is not linear. Although the approach can uncover solutions that have nothing to do with information system hardware and software, needs do have to be filtered to a reasonable range of action. The focus here is on information systems within the ITS, and it is assumed that winter maintenance strategies and organization is largely fixed. But information systems have the power to change operational strategies and organization, which is what section (4) of the OCD is about. Therefore, the process of needs and solutions is iterative. The STWDSR of this year will not be final. System evolution is facilitated by the open-systems architecture of the ITS.

Requirements are in section (3) of the OCD. Within the system development process, there is a hierarchy of requirements, down to construction specifications. These are not properly in the OCD. However, the FHWA role is not as an operator or builder of the ITS. Requirements as conceived here will not be at a low level, but will be somewhere between the higher level process specifications and what is called for in software (or hardware) requirements specifications within the MIL-STD-498 framework. The objectives are to move the RWIS market toward integration and service as envisaged by the ITS architecture.

Therefore the section (4) operational scenario description also acts to portray requirements, by examples of use.

A draft version of the guidance document (V1.0) was produced in September, 1999, that describes the approach and performs the needs analysis. While this will be used by the FHWA internally, it also serves as a primary input to the Office of the Federal Coordinator for Meteorology (OFCM). The OFCM, through its Weather Information for Surface Transportation Joint Action Group, is combining these requirements with the surface transportation requirements of other federal agencies. Once all these requirements are combined, they will serve as the foundation for possible changes in the delivery of products by the federal weather providers. The OFCM held a surface transportation symposium in late November that initiated this effort. Included in the symposium were the intended stakeholders: state DOT maintenance staff, system developers and the National Weather Service (NWS). The stakeholder group will participate in two further STWDSR review meetings to produce V2.0 by July, 2000.

III Needs and Needs Analysis

The statement has been made justly that more than enough effort has been expended on collecting "needs". The FHWA Weather Team held a needs workshop in 1997 as the basis of the white paper. The rural ITS program held another needs workshop, including weather information, in April, 1999. These were by no means the first or last such efforts. The STWDSR V1.0 contains a table of 423 "needs" for all surface transportation decision makers, and 23 just for the focal winter maintenance group.

The needs are defined as the kinds of decisions that are made with respect to weather effects on the surface transportation system. Decisions are made for the sake of actions, and there are four types of actions that can be taken:

1. Treatment to mitigate effects of weather on the system (e.g., anti-icing, clearing snow).
2. Coping by changing activities with respect to conditions (e.g., delay a trip).
3. Response to incidents, damage and other negative outcomes due to weather (e.g., search and rescue).
4. Seeking of weather conditions, usually for recreational trips (e.g., skiing), measurement or preemptive response.

Another important categorization of decisions is by scale. From meteorological usage, there are climatic, synoptic, meso and micro-scales. These relate to characteristic space-time extents and predictive horizons of weather. Decisions have scales as well, in terms of the spatial dimension and lead-time required for action. Scale is a key principle used by the STWDSR to relate information processing to the needs. For operational analysis it is generally sufficient to use three scale categories:

1. Micro, or warning scale: Very local (vehicle, road segment) and short-horizon (up to several minutes) decisions.
2. Meso/synoptic or operational scale: involving management of distributed resources at time horizons from sub-hour to several hours.
3. Climatic or planning scale: involving emplacing relatively fixed resources or preparatory to operations.

The full needs table in the STWDSR V1.0 is organized by type of decision maker and scale. Forty-four decision-maker types were identified. Table 1 shows the portion for winter highway maintenance. Actions such as traveler advisories are not within the initial STWDSR scope, except via operational coordination decisions of maintenance.

Table 1: Scaled Needs for Winter Highway Maintenance

Micro (warning)	Meso/Synoptic (operational)	Climatic (planning)
Control spreader	Detect weather event	Treatment planning
Control plow	Schedule crews (split shift)	Hire staff
Control static (bridge) Anti-icer	Prep. equipment	Train staff
Observe/report	Mix/load expendables	Buy equipment and services
Navigate truck	Dispatch crews	Stock stores
	Program treatment control	Budget
	Repair/adjust equip.	Seasonal tasks
	Coordinate (e.g., traffic mgt.)	Calibrate controls
	Request aid	
	Dispatch damage repair	

The needs analysis worked backward from weather threats to transportation outcomes to treatment strategies represented by the decision/needs. The threats at issue for winter highway maintenance treatment are essentially snow, ice, and the combination of wind and snow (drifting). All the decisions in Table 1 are for the sake of treating these threats, and the treatment strategies come down to:

1. Pre-treatment or anti-icing: application of chemical to depress freezing point and prevent bonding of ice to pavement.
2. De-icing: application of chemical, heat and mechanical stress to breakup ice.
3. Plowing: mechanical displacement of surface snow and ice. There are variations of bulk removal and thermal melting.

When the treatment strategies are traced back through the decisions, and consideration is made of the "physics" of each treatment, a list emerges of what has to be known, in space-time dimensions, to control the treatment.

It is also a principle that uncertainty is inherent in decisions because they are always for prospective actions in situations that past data do not determine completely. In considering the relation of decisions to outcomes, error bounds are intuitively used: There is a balance between missing true alarms, and acting on false alarms. The aversion to doing nothing when a weather threat occurs tends to create risk decision criteria that accept more false alarms than missed alarms. The WIST-DSS should deliver probabilistic information on the risk-weighted payoffs to outcomes. Risks may be interdependent over a scenario of predicted storm events since acting on false alarms can impair acting on later true alarms through commitment of finite resources, such as crew time. Also, pre-treatment too early in a storm, especially if there is a rain-to-ice transition, wastes the application and accrues environmental costs.

IV Operational and Weather Scenarios

The values of parameters that trigger the treatment actions (e.g., time to 0°C road temperature, chemical concentration, snow-cover depth) can be derived in part from the literature [e.g., Ketcham et. al., 1996]. However, it is difficult to relate these to the ultimate outcomes. Further outcome evaluation is desirable, and is underway for the Foretell operational test under FHWA sponsorship [Battelle, 1999]. However, improving the RWIS cannot wait, and evaluations of an improved WIST-DSS must come after deployment. Therefore, stakeholder participation is essential in better defining the practice of how decisions are made now, and prospective improvements through new technology and operations. The STWDSR is involving six national labs in the United States that are involved in advanced weather information systems development. These labs are sponsored by the NWS and others, and it is our intent to introduce their innovations into the surface transportation domain.

Stakeholder participation has already been associated with "needs", but the STWDSR will take it to requirements. The tool for doing this is the creation of example scenarios of operations and weather. An operational scenario is a time sequence of information consultations and treatment actions. Since timing is a critical parameter to be determined, these can be constructed only in part from what is known from the needs analysis. By laying out examples, experienced managers can fill in details and suggest parameter values. The actions are made in response to weather events, and other information on the state of the transportation system. Therefore the operational scenarios must be related to example scenarios of weather events.

The weather scenarios are constructed from archived data from the National Environmental, Satellite, Data and Information Service (NESDIS). These are presented in graphical (radar, satellite) and textual (watches, warnings) form for real storm events. The three selected weather scenarios are: (1) a "surprise" snowstorm that developed over Washington, DC in the late winter of 1999, (2) a devastating ice storm that plagued portions of the Deep South of the United States during the 1998 Christmas holiday season, and (3) an early season blizzard in the Western Great Plains of the United States in late October, 1997. These weather scenarios affected large areas with varying densities of population and topography. The "surprise" that occurred in the DC storm was that a narrow swath of snow, a foot in depth, that accumulated during a work and school day over a high density metropolitan area when only a few inches were expected. The road system became highly jammed, impeding plow crews. The second event was a devastating ice storm that destroyed power grids, toppled countless trees and stranded many in and around metro areas such as Birmingham, Alabama. The third event was an early-season blizzard in the Western Great Plains of the United States that produced three or more feet of snow in late October, 1997, affecting Denver and the front range eastward.

The weather scenarios represent what weather information is known. Stakeholder response will be used to connect the operational decisions with available, and desired, information, and to respond to the way data are presented. When an operational and a weather scenario are connected, the result is requirements for the WIST-DSS. By understanding the NWS and vendors' capabilities, the demand for "perfect forecasts" will be tempered. At the same time, the most critical relations between the outcomes and missing information, or inadequate presentation of information, can be identified. This prioritizes deficiencies for redress by the WIST-DSS.

V Expected Results and Conclusions

The prior belief is that there is much more weather information available than is used by highway winter maintenance personnel. It is also assumed that NWS products are about as good as technology and budgets allow. It is expected that requirements for the WIST-DSS will be allocated primarily to the collection of road-condition information through fixed and mobile ESS, and to the tailoring of multiple sources of information through filtering, fusion and presentation. A requirement that is less clear is for finer-scaled meso-modeling to use and augment segment-specific road condition forecasts and observations. There is a gap in the micro-meso scale that needs to be filled by better fusion of point observations, remote sensing and numerical modeling. This especially is where some of the state-of-the-art developments can be applied. Fusion of disparate data sources is another area where probabilistic information (e.g., for fuzzy logic) is important.

NWS interfaces are a focus of the STWDSR, through the inter-federal coordination provided by the OFCM. However, surface transportation is a decentralized activity, with many kinds of public and private customers, for whom tailoring will be needed. The main intent of the STWDSR is to promote the combinations of technology, meteorological services, public-sector funding and customer demand that will lead to WIST-DSS deployment. With respect to the FHWA Weather and Winter Mobility program, the requirements will be the basis for future program activities to support WIST-DSS deployment.

VI References

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