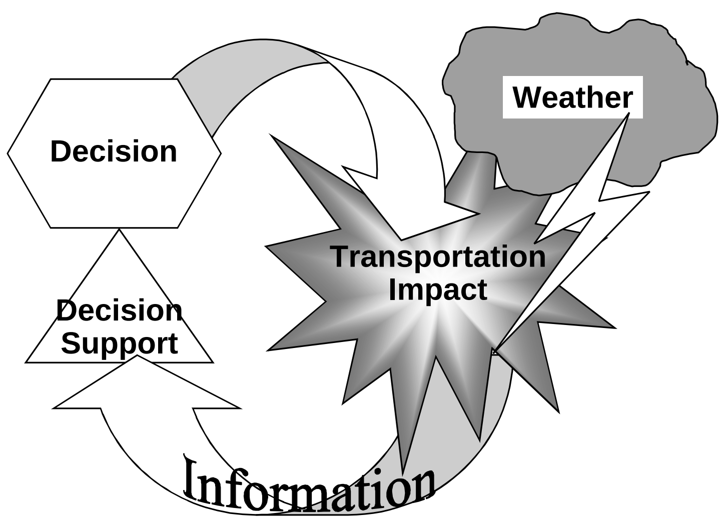
Surface Transportation Weather Decision Support Requirements

Executive Summary
Draft Version 1.0



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for

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by
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Executive Summary

Purpose

Weather: It affects the visibility, tractability, maneuverability, vehicle stability, exhaust emissions and structural integrity of the surface transportation system. Thereby weather affects the safety, mobility, productivity and environmental impact of that system. The weather cannot be controlled significantly, but all transportation decision makers need information about the weather to treat and cope with its effects. 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).

This Executive Summary gives an overview of the key parts of the requirements definition process: Analysis of *needs* for information by each type of surface transportation decision; Stakeholder participation in converting their needs into *requirements* on a decision support system, and; Identification of the high level *structure of an advanced decision support system*. The full report also gives considerable detail on current weather information and its delivery.

This summary covers the STWDSR version 1.0 (V1.0). The intended audience of this summary and the full report are the potential users and developers who are the stakeholders in deployment of surface transportation weather decision support systems. STWDSR V1.0 provides necessary background information to the stakeholders who will participate in the requirements-definition process. Their participation will result in the STWDSR V2.0 document, in June, 2000 that will also be a product for FHWA and other federal program managers.

The process and aims of the STWDSR project are illustrated in Figure ES.1. In the near term, the STWDSR will document requirements on a conceptual system that delivers information to users, who are all sorts of decision makers (traffic managers, road maintainers, transit and other fleet operators, drivers, shippers, etc.) in the surface transportation system. The users have goals for the performance of the surface transportation system. The decision makers need information to meet the goals effectively via operations on the surface transportation system.

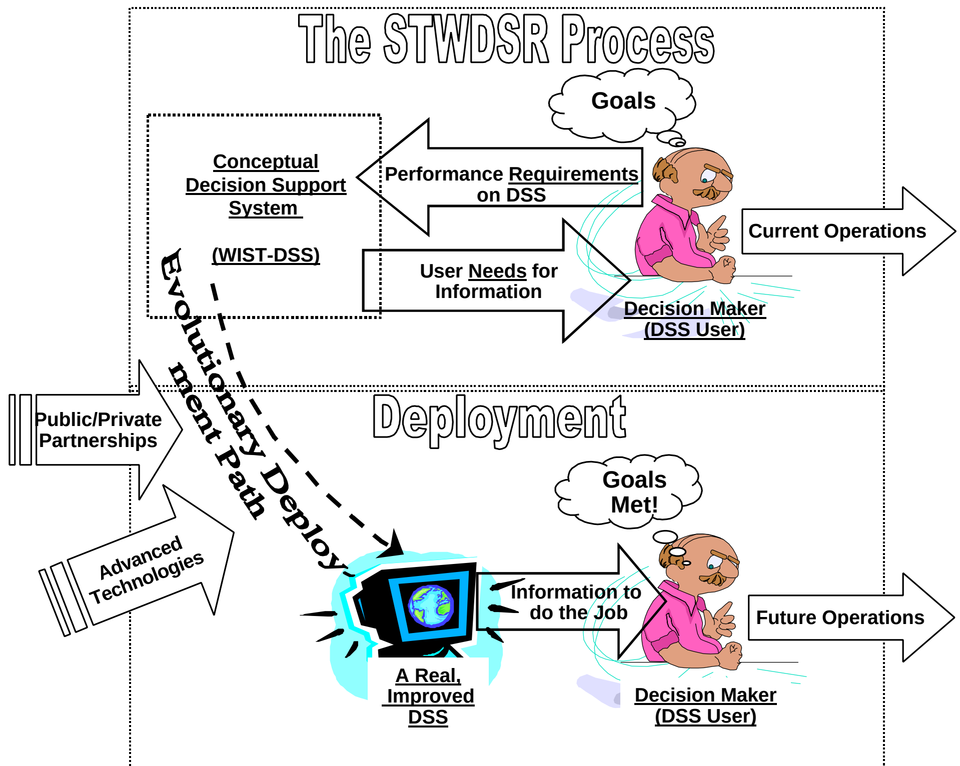

Figure ES.1: Overview of the STWDSR Process and Its Relation to Deployment

The STWDSR process is about involving decision makers in the translation of their needs for information into requirements on an advanced and conceptual decision support system. The conceptual system will be called the Weather Information for Surface Transportation Decision Support System (WIST-DSS). The users have the *needs*, the WIST-DSS has the *requirements*.

The STWDSR documents will define a full range of needs, as types of decisions made by surface transportation operators and users. However, the level of effort needed for needs analysis and stakeholder participation constrains the scope of the requirements produced. Both STWDSR V1.0 and V2.0 will focus on winter road-maintenance requirements, and will create the basis for expansion to the other decision-maker groups.

Documenting the requirements will promote and coordinate deployment of a future decision support system to meet the needs. The FHWA will not deploy this advanced system, nor will the requirements be conditions for federal-aid funding. The WIST-DSS will be defined only at a high level. There will be an *evolutionary* path from the current systems, collectively called the Road Weather Information System (RWIS) to the future systems, as the STWDSR are used successively to improve parts of the RWIS. Real systems will be deployed by developers for customers in various ways that employ evolving technologies and that adapt to local needs. The future system will be decentralized and have many manifestations that tailor information for different kinds of users. The FHWA envisages that the STWDSR will find its way into deployment both through entirely new decision support systems, and by the incremental improvement of current systems.

In order to foresee technological opportunities and to recognize practical deployment issues, the system developers are also part of the stakeholder group, along with users, that will be brought into the STWDSR process. Weather information in the United States mixes the endeavors of public agencies under the National Oceanographic and Atmospheric Administration (NOAA) of the Department of Commerce (DOC), and the private sector. Under NOAA, the NWS is the primary provider of weather information, and its products are further tailored by Value Added Meteorological Services (VAMS) under the private sector. The systems used by both the NWS and VAMS are mostly built by the private sector. However, NOAA and other federal agencies sponsor laboratories active in meteorological information systems development. The STWDSR process will leverage the technology know-how of both the private developers and the Anational labs@.

There are few surface transportation decisions that require *only* weather information. In fact, weather information, which is about the state of the atmosphere, is of little direct interest. What is needed is information on the state of the surface transportation system, as affected by weather and many other natural and human events. The WIST-DSS does not intend to tackle the entire set of information needs by itself. The WIST-DSS is firmly within the context of the Intelligent Transportation System (ITS) that will provide the full scope of information. The WIST-DSS is also in the context of the NWS and VAMS that provide weather information. The focus of the STWDSR is squarely on the filtering, fusion, processing and presentation of information via the ITS that includes weather information. The STWDSR is deepening and elaborating those parts of the ITS dealing with weather information.

It is an axiom of systems development that information changes operations. The STWDSR is based on detailed analysis of current operations to derive needs and define requirements. Changes in operations, information technology and aspects of the surface transportation system are all part of systems evolution. In this sense, the STWDSR process cannot end. The focus is on those high level structural and functional requirements that should persist to guide deployments for a reasonable time into the future. Goals tend to be persistent, and this process is goals and needs oriented, as is the National ITS Architecture. But going the next step toward deployment coordination involves looking at technologies that will change. The STWDSR is a middle-term coordination framework, in between the National ITS Architecture and specific deployments.

At the highest level, the requirements for better decision support are commonly known: timely, accurate and relevant information. The problem is that weather information that is about the atmosphere (and generally well above the ground surface) has to be converted to sensible effects on specific surface transportation facilities in time to make decisions about the those facilities and the travel on them. The information always has to be predictive, since decisions act into the future with time horizons from sub-seconds for drivers to hours for mobilizing operational assets, to months for obtaining those assets. High resolutions are demanded, down to bridge decks or any road segment that is climatically distinct, but weather data are rarely that fine because they serve predictions for the atmosphere that generally is more homogeneous than the ground surface. There are limits set by the physics of the atmosphere on the feasible combinations of accuracy, resolution and time horizon.

Realistic, decision-specific, and quantitative requirements will take a great deal of effort and must examine each kind of decision maker in turn. The needed level of effort determines that the initial STWDSR process must focus on one decision-maker group, and winter road maintenance has been chosen as the priority.

The format of the STWDSR documents follows the Operational Concept Description (OCD) format from system engineering standards, while adding the preliminary needs analysis material. The logic of the OCD format is simple:

1. Define the scope of the system receiving requirements (the WIST-DSS).

2. Define the current system and the operations it supports.

3. Define current performance deficiencies that justify system improvements.

4. Define the concept of the improved system.

5. Show how the improved system will operate.

6. Summarize the impacts of deploying the improved system.

The important points are that the scope is bounded, and the improvements are driven by operational needs, not the technology. Technology is the means to the improved system. The order of sections is modified in this document, mainly because the operational concepts developed in the fifth part are initially used to show current operations as part of needs analysis. In V2.0 this will be reversed to show how the improved system, the WIST-DSS, will work. The OCD is intended to contain a high level of requirements. More detailed requirements that lead to deployment will follow other formats.

Background

The FHWA Weather Team was formed in 1997 to coordinate surface transportation weather programs and advance the use of weather information within the ITS. The Team=s findings and program are contained in a White Paper[1]. The White Paper found that the most apparent deficiencies in the RWIS are in decision support, defined as the filtering , fusion, processing and presentation of available weather and other surface transportation information. This defines the focus of the STWDSR, and is distinct from the quality of the weather observation and prediction sources used by decision support.

In 1999 the FHWA was reorganized and weather programs were consolidated under the Weather and Winter Mobility program in the new HOTO office of the Operations Core Business Unit. The first mission assigned to the Weather and Winter Mobility program was the definition of weather information requirements of road users and operators. This includes requirements affecting inter-federal coordination, such as between the FHWA and the NWS. Since then, the Office of the Federal Coordinator for Meteorology (OFCM), the agency responsible for such inter-federal coordination, has extended its activities to include surface transportation weather issues. Previous USDOT activities with the OFCM have focused mostly on aviation issues. The STWDSR then become part of OFCM=s surface transportation requirements process.

The Weather Team and subsequent activities grew out of the ITS program=s concerns for information in surface transportation operations. The STWDSR project intends to promote deployment of those parts of the National ITS Architecture[2] concerned with decision support involving weather information. The National ITS Architecture also promotes an evolutionary deployment path by specifying an open system. An open system would correct the most apparent deficiency of the current RWIS: There are too many sources of information that cannot be fused satisfactorily into tailored support for specific decisions.

[1] Weather Information for Surface Transportation, FHWA, May 15, 1998. Available as document 11263 at the Electronic Document Library, accessed through: http://www.its.dot.gov/welcome.htm

[2] National ITS Architecture. Hypertext Architecture Version 2.2, generation date 6/1/99 found at: http://www.odetics.com/itsarch/.

Meeting requirements for information *fusion* depends on comparing the statistical or risk measures of the reliability of data sources, and on using open system principles. Achieving an open system in turn requires addressing some institutional issues, to allow data access by modular applications that can filter, fuse, process and present large quantities of four-dimensional (space-time specific) information. Such a system must be able to match the scale of decisions to the scale of information (especially the relevant time horizon) and use geographic information system (GIS) databasing.

Focusing on the quality of weather information going *into* decision support is appropriate only when decision support requirements are met. Deficient relevancy of information has to do with the conversion of *weather* information into *road-condition* information within the decision support system. Deficient accuracy of information must be related to the scale of information needed by a decision, in terms of spatial resolution and time horizon. Weather predictions from the NWS generally are considered too coarse to apply accurately to specific road segments. But this applies to the results of complex numerical weather prediction models, designed for multi-hour to multi-day horizons, and overlooks use of the voluminous observational data (including remote sensing data from radars and satellites) that goes into the models and is applicable at the smaller scales. Small scaled road-condition information is observed directly by fixed and mobile Environmental Sensor Stations (ESS). The extrapolation of conditions from a limited number of ESS sites (about 1000 currently in the U.S.) to the 4-million route miles of U.S. roadways is a problem, requiring fusion and processing of the appropriate weather and road-condition data, as in heat balance modeling for road surface temperature.

The focus of the STWDSR is also stipulated by the institutional constraints between the public and private sectors concerning the tailoring of information. A private VAMS market should flourish. The NWS should also flourish as the public-sector provider of weather observations and predictions, at national and international scale, and of the severe weather watches and warnings critical to public safety and commerce. The bounds between what the NWS and VAMS can do is not precise. The tailored decision support focused on in the STWDSR is *mostly* outside of the NWS domain, and *mostly* within the capability of VAMS to provide. It is in the domain of the FHWA to mobilize additional public-private effort to realize the requirements for decision support, and to be one of the supporters for ongoing improvement of NWS products.

The STWDSR Process

The STWDSR process was established to bring together the knowledge of operational users (initially winter road-maintenance managers), and the private vendors who will provide evolutionary system improvements, aided by the unique national laboratories involved in meteorological decision support systems under sponsorship of NOAA and other federal agencies. These are all the *stakeholders* in the process. Mobilizing this knowledge toward a set of requirements and a vision of the WIST-DSS is the job of a systems engineering contractor, Mitretek, that has been supporting the ITS and FHWA weather program since its inception. The schedule and basic tasks of the STWDSR project are shown in Figure ES.2. The STWDSR project was initiated in May of 1999. Its objective is to deliver a final STWDSR document that covers winter road maintenance by June, 2000 while also providing the framework for analyzing and meeting needs of other road users and operators. It intends to do this through two rounds of stakeholder review of STWDSR V1.0 and subsequent documents leading to V2.0. Users will be solicited primarily from state Departments of Transportation (DOTs) and the private vendors from a public solicitation.

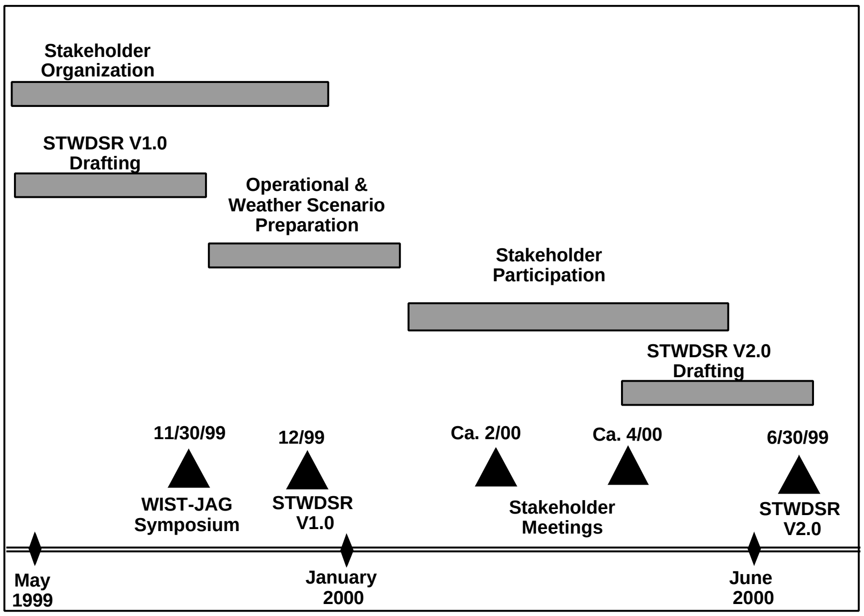

Figure ES.2: STWDSR Process Schedule

Six of the national laboratories are to be included by subcontract and will support Mitretek in defining applicable system technologies and reviewing requirements. The selected labs are:

$ The Army Corps of Engineer=s Cold Regions Research and Engineering Lab (CRREL)
$ NOAA=s Forecast Systems (FSL), National Severe Storms (NSSL) and Environmental Technology (ETL) Labs
$ MIT=s Lincoln Laboratory operated for the U.S. Air Force, and;
$ The National Center for Atmospheric Research (NCAR) operated by the University Consortium for Atmospheric Research (UCAR).

In addition to the STWDSR documents, Mitretek will prepare scenarios of selected winter weather events and operational decisions for presentation to the two stakeholder meetings. These will elicit from the users the parameters on the information desired for each decision. The vendors and national labs will present technology applications to address the requirements. In this way, the needs and opportunities can converge on a realizable system concept.

The process has the no-less-important purpose of introducing the stakeholders to each other. The stakeholders will be responsible for deployment, and the meetings will be an opportunity to start forming the partnerships necessary for deployment.

User Needs

User needs are defined as the decisions made to meet the goals for performance of the surface transportation system. The FHWA has the strategic goals of Mobility, Safety, Productivity, Human and Natural Environment and National Security. Road user and operator goals generally are versions of these. These goals can be met by maintenance of adequate road levels of service (LOS) through snow and ice treatment, with efficient treatment-asset control to reduce costs and minimize use of chemicals.

The decision makers have information needs that become WIST-DSS requirements through analysis of the needs. A full list has been generated of 426 needs across 44 user types in surface transportation (operators, travelers and users of transportation services). Twenty-three (23) of the needs are for winter road maintenance management, as shown in Table ES.1.

Needs analysis is the process of allocating needs to different kinds of solutions, and then developing the requirements for the kinds of solutions. For instance, there are organizational solutions (e.g., better integration of traffic management and maintenance) and there are operational solutions (more use of ice pretreatment rather than deicing). The scope here has been limited to decision support involving weather information, based on the prior analysis in the Weather Team White paper.

In moving towards requirements, scale is used as a key categorization of needs, because that matches the decisions (needs) with types of information. Weather information has scales based on the physics of the atmosphere. These go from the largest (climatic) scale to the continental span and days horizon of the synoptic scale (large air masses and fronts) and the meso scale of counties and hours covering convective storms. The micro scale is of very local and immediate detail (within kilometers and minutes). These weather scales map to decision scales that have been categorized into three groups called planning, operations and warning. These decision scales relate to asset preparation, asset mobilization and asset deployment, with specific examples shown in the table for winter road maintenance.

Table ES.1: The Needs Table for Winter Road Maintenance

		Micro-Scale	Meso/Synoptic	Synoptic/Climatic
User#	**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

Weather information scales generally have quite distinct sources such as direct observations, filtered/extrapolated observations, localized numerical prediction models, national numerical prediction models, and climatic time series or predictions. One of the deficiencies of the current RWIS is the failure to fuse information especially in the micro-to-synoptic scale range that spans operational decisions, from immediate ESS readings to multi-day national forecasts. Voluminous remote sensing data, especially from radar and satellite, offer the best hope for improving short-range operational decisions about where and when to dispatch assets, especially for anti-icing pretreatment. ESS data should be assimilated with other observations for quality assurance and to feed tailored road-condition forecasting models, along with weather forecasts. The climatic scale is generally distinct from operational uses, but it is vital to decisions about resource availability that ultimately determine cost and treatment effectiveness.

Needs analysis for winter road maintenance proceeded by considering what the weather threats are to roads and what treatments are done to mitigate those threats. Treatment types are analyzed into the space-time distribution of actions that must then be based on specific kinds of information. The risk concept is introduced by considering what the penalties are for missing alarms or treating false alarms of storm or icing events. This creates the operational scenarios that, in combination with sample weather-event scenarios, indicate *what* information is needed *when* and for what spatial domains (*where*). Stakeholders will review these scenarios for their fidelity to real decision making and to evaluate the information needed.

Scope of the WIST-DSS

As requirements are better specified, through efforts such as the STWDSR project, real systems can be deployed incorporating evolutionary improvements. The ultimate system specified by the requirements is called the WIST-DSS. The WIST-DSS will improve the baseline RWIS. In focusing the requirements work, it is important to bound the domain of interest. The WIST-DSS is bounded as shown in the context diagram of Figure ES.3.

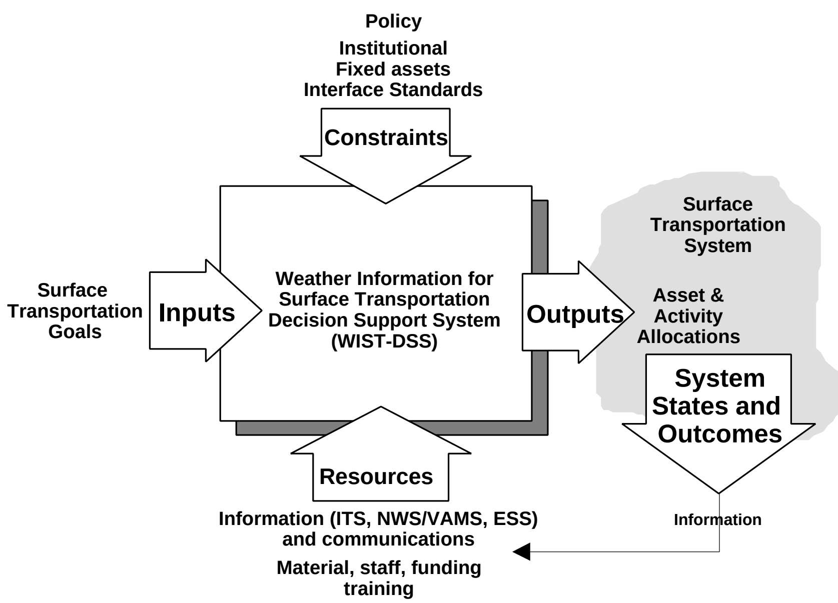

Figure ES.3: WIST-DSS Context Diagram

The context diagram includes inputs, resources and constraints received by the WIST-DSS, and outputs generated by the WIST-DSS. It is important to note that the inputs are not information sources, but the surface transportation performance goals that motivate decisions. Decisions responding to goals and supported by information as a *resource* generate outputs that are the allocation (control) of assets in the surface transportation system. The WIST-DSS connects the inputs and outputs via an informational system for decision support.

Resources also include staffing, funding and training for users. These all have to be provided externally to the decision support system itself. This bounding is important, and implies that the scope of this project does not include the generation of weather and transportation informationBthat is the role of the ITS (and the ESS within the ITS for road condition observations), the NWS and VAMS outside the system. The WIST-DSS is concerned with better resource utilization for goal attainment.

Constraints also are beyond system requirements, but part of the STWDSR process is to point out policy issues requiring attention by the FHWA and the stakeholders. The following issues have been identified:

$ Proprietariness: Protecting information and system property rights while not creating barriers to the open system.

$ Security: Protecting the integrity of information systems while promoting legitimate access in the open system.

$ Liability: Raising benchmarks of information delivery so that information is used, rather than witheld, to improve transportation performance.

$ ESS Performance: Issues of investment and maintenance and the ability to assimilate observations with the NWS.

$ System Capacity Allocation: An open client-server architecture creates an informational infrastructure that, like the public highway system, raises issues of who bears the cost of information and how these are allocated through payment by users.

$ Financing: How the financing is split between the public and private sectors.

$ Public and Private Sector Roles: Especially between the NWS and VAMS for particular parts of both providing information resources and tailoring them within the WIST-DSS.

Figure ES.4 is a functional view of the WIST-DSS and shows where the focus of requirements allocation will be: It will be on the parts inside the WIST-DSS and its interfaces to external information resources. Requirements are validated only by improved performance of the surface transportation systemBthe outcomes that result from outputs of the WIST-DSS. Requirements validation is a long process that must extend beyond the present project and await operational tests or deployment. The Foretell J system, an operational test of the FHWA Weather Team, will have a three year evaluation and will be one of the sources of requirements validation, but other deployments must be similarly evaluated.

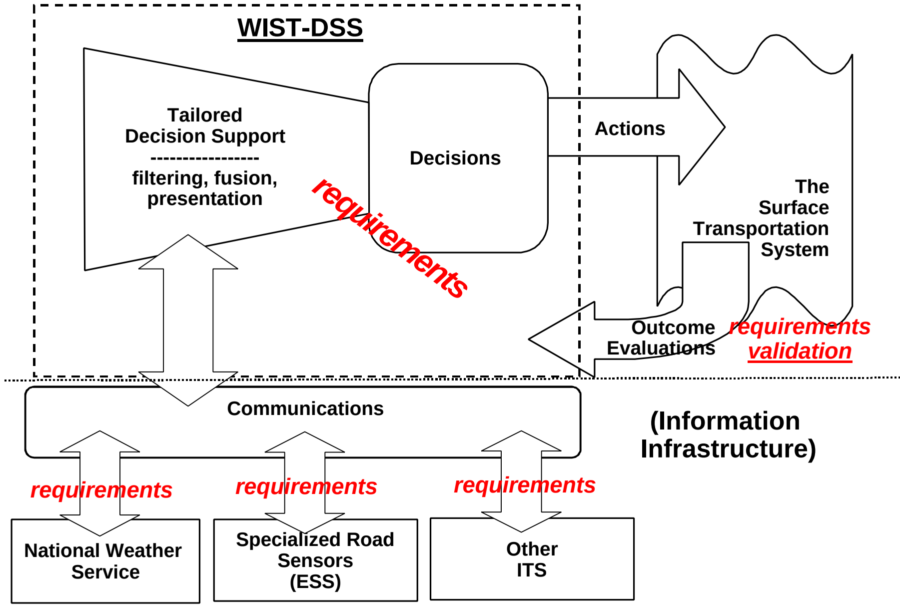

Figure ES.4: Where Requirements are Allocated and Validated in the WIST-DSS

The main focus of requirements is on the tailoring of information in decision support. This strongly reflects the main axiom of this project, that there is lots of weather information and a severe shortage of filtering, fusion, processing and presentation that serves specific decisions. The information interfaces already are largely specified by the National ITS Architecture and NWS products and systems under the NWS modernization program. ITS standards include the ESS interface, but the ESS is shown separately since there are issues of how the road-condition data eventually will be assimilated (through the ITS, through the NWS, or through the VAMS).

The first-order assumption is that the interfaces are sufficient. Realistically, surface transportation requirements will not drive the NWS, and weather information is not a dominant part of the ITS. However, good analysis of the performance impacts of weather information through decision support can influence future ITS and NWS development. The most immediately affected should be the VAMS products, that will include WIST-DSS components themselves. Passing requirements to the National ITS Architecture and to the NWS will be primarily a federal role through the FHWA.

There are significant technical issues in the use of ESS observations, involving the fusion, model-processing, and presentation within the WIST-DSS. The issues are how well road-condition predictions, especially of surface freezing, can be made by heat-balance modeling solely with meteorological inputs, versus prediction solely from ESS point observations (and their spatial extrapolation by thermal mapping), or a combination of these.

Current Context and Practices

The current deficiencies of the RWIS and its context are the springboard for the WIST-DSS requirements. The operational context is the highway system that is treated for snow and ice. The functional context is primarily the information interface to the ITS and the NWS.

The operational context includes a huge (4-million route mile) network of U.S. highways categorized by functional class and jurisdictional responsibility. A key fact is that the functional importance of the route network is highly skewed, with only 5% of route miles (including the National Highway System) carrying 50% of all vehicle miles traveled (VMT). This sub-network is mostly under state jurisdiction, although winter-maintenance practices vary from state-operated to contracted. Cost characteristics tend to indicate a focus on this sub-network for maintaining road LOS under weather threats. Yet the remainder of the network cannot be ignored, and requires great treatment efficiency improvements if it is to be maintained effectively. The augmentation of point-sensing of road-conditions by mobile and remote sensing is a major factor in this efficiency.

In winter road maintenance, there has been growth in the use of pretreatment and this depends heavily on RWIS information. Pretreatment is the deposition of chemicals to prevent surface freezing and the bonding of overlying snow to pavements via an ice layer. Doing this efficiently, and to preserve biota and watersheds from excess chemical contamination, requires good predictive surface-freezing information. Application controllers on maintenance trucks can be controlled by mobile road-condition sensing. With automatic vehicle location and data communications between trucks and base, more observational data are available and innovations can be made in the central-versus-mobile allocation of decisions.

Today, the RWIS does everything the WIST-DSS will, but the issue is how well. The RWIS, in its broad definition, provides weather and road-condition information to maintenance managers, and has been doing so for decades. More recently, some federally-sponsored projects (the Advanced Transportation Weather Information SystemBATWISBin the Dakotas and Minnesota, and soon Foretell in Iowa, Missouri and Wisconsin) and several private ventures have extended road-specific information to travelers by various dissemination media. The RWIS information extends from just its ESS data to general meteorological forecasting services by VAMS, and includes the usual weather presentations from Information Service Providers (ISPs) like TV and radio broadcast. All meteorological products, and some road-condition products, ultimately are supported by the NWS infrastructure.

The ITS context is defined voluminously by the National ITS Architecture and its standards. Many standards are still under development, and the ESS standard is not a Acritical@ one required for federal-aid. Weather information and maintenance are two areas not as well developed as others in the National ITS Architecture. Therefore, although the first-order assumption is that the National ITS Architecture provides a stable context to feed transportation information to the WIST-DSS, and to disseminate controls from the WIST-DSS, a closer look is likely to identify many interfaces that need better specification.

The NWS is, with its modernization, a vast and high-quality meteorological information source. As its remote sensing (radar and satellite) assets improve, as its forecast modeling products increase their frequency and resolution, and as the Weather Forecast Offices (WFOs) with their Advanced Weather Interactive Processing Systems (AWIPS) produce more digital-graphic-GIS products, the volume of information into the WIST-DSS increases. The first-order assumption here is that the information is as good as public-funding resources permit and that tailoring it for specific users is the main challenge. But if a public-interest argument can be made on behalf of the surface transportation sector, as it has been for aviation, more funding for improved NWS products can be motivated. Also possible are joint FHWA-NWS programs, emulating the partnership of the NWS with the Federal Aviation Administration (FAA) and the Department of Defense (DOD). But the public-private split of responsibility and the constraints on Atailoring@ raise very practical issues of whether services, as for finer-scale numerical weather modeling, should be provided by the NWS, bought by the public sector from VAMS, or even operated directly by public agencies like DOTs.

Needed Improvements

Even before detailed requirements analysis, some shortcomings needing improvements are obvious:

1. Information is not integrated.

2. The reliability of information usually is unknown.

3. Information is not route-segment specific.

These deficiencies relate to the Atimeliness, accuracy and relevance@ requirements, but deficiencies in the information resources have to be separated from those within the scope of decision support.

Regarding deficiency (1), a typical maintenance manager will have four, five or more discrete (Astovepiped@) sources of information requiring manual Aswivel-chair@ integration. Such manual integration cannot process and make sense of the information that is obtained. Scales of information, especially observations and forecast models, are segregated, and very little has been done to fill the 0-2 hour regime with better extrapolation of remote-sensing data, especially radar data on precipitation. The RWIS is not an open system, and the development of applications for filtering, fusion and presentation of information has lagged. Appropriate fusion of different information sources at different scales can do much to address timeliness and accuracy, as well as relevance of the presented decision support information.

It is hard to say anything about weather information accuracy, or the cost of its deficiencies until there is more information on the quality of information resources. Deficiency (2) is about the lack of statistical measures on observation and predictive error and variance from different sources at different scales. There is reasonable information on error and variance only for point-temperature measurements and predictions from ESS. Reliability assessments for all information sources is a *tool* for information fusion, processing and risk-decision making. Reliability measures can be produced by statistical approaches to information generation (ensembles of models and observations, or time series products). Using the central statistics (e.g., average values), of information from these processes can also improve decision making.

Deficiencies (2) and (3) are connected. There is a practical limit as to how accurate and route-specific information can be at a given time-horizon. This can be revealed only by the statistics on information-source error. This should result in a shift from unrealistic demands on complex numerical prediction models, to more emphasis on risk-decision making and appropriate fusion of different data sources. While much attention has been given to use of finer scaled meso-models for weather prediction, beyond that provided by the NWS, the gap between use of observations and available NWS forecast products may be quite narrow, and keeps getting narrower. Good information fusion and processing, other than in high-resolution atmospheric numerical models, could substantially close the gap for many operational purposes.

Regarding the information resources, point pavement temperature measurement and prediction from fixed ESS is quite good if maintenance and data filtering are done appropriately. One of the blessings of nature is that surface-temperature prediction tends to be best around local midnight when homogeneous, stable air reduces variations in temperature. Thus, the most critical time for surface freezing is best predicted. However, performance from extrapolating point ESS data to extended route segments is less well known. With about 1000 ESS for the 4 million route miles in the U.S., this is a significant issue. This limitation can be overcome through thermal mapping and heat balance techniques. Thermal mapping requires climatological information on surface temperatures away from the fixed ESS site, and that requires mobile or remote-sensing radiometry. Heat balance modeling depends both on mapping the radiative characteristics of roadways and the quality of meteorological prediction.

Performance of general meteorological prediction is limited by observational data inputs (that also are needed for assessing that performance). But it is not simple to choose relevant performance measures for information over areas and volumes relative to decision risks. It is known that the skill of NWS products has improved steadily over the decades, and can be improved further in local domains by ESS and remotely-sensed data used by itself and to feed high-resolution numerical models. We have almost no idea what an increase in skill means for costs or effectiveness of winter road maintenance. Higher resolution numerical models probably means reducing their spatial domain, resulting in many local models being run, and not under NWS auspices. While this can be the basis for ensemble products, there is a deficiency when the models are fragmented into many uncoordinated and un-validated local domains. This is a fusion issue of the WIST-DSS, also involving the interface with the NWS, the interests of VAMS and policy constraints on tailoring.

Improvement Concepts

In the logic of the Operational Concepts Description (OCD) format, the deficiencies imply the improvement concept. In other words, where the RWIS is lacking, requirements lead to the WIST-DSS. The introductory material presented here has already given a good idea of what the WIST-DSS will be like. It will be a goal-driven, user (decision)-specific, open/integrated decision support system within the ITS. Not much more can be stated at this stage. The STWDSR process will develop more detailed requirements. The requirements are not going to reach the level of a Abuild-to@ design specification. Since the FHWA will not be involved in specific deployments, and will not require a uniform design, that is not a mandate here. The requirements will be of a level to inform the interfaces (especially the ITS and NWS), to create a uniformly, but realistically, demanding customer base for better products, and to identify where standards may be necessary. The requirements will be closer to best practices, documented as operational scenarios, than to system design specifications. That is why the OCD format is chosen for their presentation.

Operational Scenarios

Operational scenarios have a dual purpose. Going into the STWDSR process, they are the means for detailing RWIS operation relative to specific treatment decisions under sample weather scenarios. Coming out of the STWDSR process, they will illustrate how the WIST-DSS is supposed to work.

This document contains information on current practices for constructing detailed operational scenarios of snow and ice treatment. It also summarizes the three weather scenarios that will be used, and the current NWS process for generating weather information. When the stakeholders see these together with ideas for decision support improvements, it will be possible to focus on more detailed specification of what should be deployed.

The operational scenarios to be used for stakeholder review will be constructed subsequently. They will be ready for the review meetings in 2000.

Expected Impacts

The OCD format requires a projection of goal-performance as the motivation of the WIST-DSS improvements. The central problem identified by the Weather Team=s White Paper is that good causal inference about the effects of weather information on surface transportation performance is rare. It is known that about 6,800 fatal crashes a year occur in adverse weather conditions. It is known that about $2 billion per year is spent on snow and ice treatment, and as much as $5 billion on repair to weather damage in the highway system. Total economic losses to reduced mobility in weather are not reliably estimated, however a one-day shut down due to weather can cost tens of millions of dollars per region. But it is a long chain of inference from better weather information, to better treatment, to reduction of *preventable* losses. Clearly, the worst storms with the biggest losses will overwhelm resources, regardless of the operational decision support provided. This just emphasizes the need for policy decisions at climatic scale that choose recurrence times for the largest storms that can be treated fully. It also emphasizes that winter road maintenance, traffic management, and traveler information need to be integrated within the ITS.

The motivating belief here is that a state-of-the-art WIST-DSS serving a state will cost perhaps millions of dollars, and suppose that amortizes to $2 million per year per state with operating costs. Over 50 states (leaving aside costs versus possible need in states like Hawaii and Florida) that is $100 million per year. If total impact-costs subject to reduction were $5 billion per year, the WIST-DSS would just have to take a 2% bite out of that to justify itself. A 5% reduction probably is realistic, above and beyond what RWIS has already accomplished. It is this rough, order-of-magnitude, result that motivates pursuit of the WIST-DSS. It is expected that incremental improvements as part of evolutionary deployment will have similar if not superior benefit-cost results, if the most serious deficiencies are addressed first. Better standards to create an open system for information resource access need cost very little and can be attained as part of normal system replacement costs.

Deployment Programs

This project is aimed at deployment, under the open-system framework of the National ITS Architecture, and with the information infrastructure of the ESS, NWS and VAMS. Deployment will be by public-private partnerships of the users and developers, with federal aid.

The product that will aid deployment is an improved and uniform vision of a system to mobilize existing resources. The federal aid available to ITS capital investments must be programmed by states and metropolitan regions. How much they appreciate the possible benefits of the WIST-DSS will determine how much of the federal and matching funds are invested.

There will still be a gap between the requirements generated here and system designs. The private vendors of systems, the developmental labs and user specifications will move toward real systems. The federal level can assist through funding further research and operational tests. The fact remains that the state DOTs control more planning and research funds than the FHWA for these purposes. Thus, this project aims to motivate projects and partnerships for states and pooled-fund consortiums.

The FHWA role includes technical support to states in various forms. Under the reorganization, regional resource centers exist, and have a few ITS resources. The Local Technical Assistance Program (LTAP) can be mobilized. This requires professional capacity building (PCB) training, user-training courses as through the National Highway Institute, and technical support materials. Translating the STWDSR results into these technical support mechanisms will be a further task. It is intended to use the STWDSR process to outline respective roles and programs for this.

The NWS/WIST-DSS interface is an inter-federal matter, which the FHWA should lead with the support of state partners, especially through the American Association of State Highway and Transportation Officials (AASHTO). The OFCM is the mechanism for this interface. The STWDSR process will identify operational tests and programs that should be pursued with the NWS and other federal agencies interested in surface transportation.