North/West Passage *Clarus*

Multi-state Regional Demonstration

Meridian
Environmental Technology Inc.

North/West Passage

Concept of Operations

prepared for
Federal Highway Administration

prepared by
Meridian Environmental Technology, Inc.

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Section 1. Scope

The *Clarus Initiative* is a Federal project that establishes a vision for the leveraging of local and regional road and rail weather observations to serve a greater community and enhance 21st century transportation operations (1). The goal of the *Clarus Initiative* is to provide broader weather information support for surface transportation system operators in their efforts to improve safety, reliability and security of transportation users. The merits of the *Clarus* System concept are supported by a National Academy of Science report (2) that concluded the primary considerations needing to be addressed from an information technology perspective for success of the *Clarus* System are volume of data, timeliness of information, and reliability of the system.

This goal will be demonstrated through a series of multi-state regional demonstrations. This document represents a concept of operations for such a regional demonstration based upon the interests and perspective of the North/West Passage Transportation Pooled Fund (herein referred to as North/West Passage).

1.1 – Intended Audience

The North/West Passage Regional Demonstration Concept of Operations is designed for a broad audience and incorporates a wide range of stakeholders in the regional demonstration concept of operations development. These stakeholders, as described later in this document, were identified from a wide range of interests extending from environmental sensor station (ESS) data owners, users of *Clarus* including the surface transportation weather service provider community and the groups they serve, application product developers, and decision makers who will depend upon a quality road weather observations dataset.

This *Clarus* Regional Demonstration Concept of Operations document is a high-level planning and visioning document intended for a wide variety of stakeholders interested in improving the use of road weather in their decision-making. The primary audience for whom the regional demonstration will be provided includes the member states of the North/West Passage Transportation Pooled-Fund Study. In turn, the participating North/West Passage states have as their intended audience those stakeholders who rely upon the government agencies within the states to provide them with the more appropriate road weather information to support their usage of the transportation system. These stakeholders also include the individuals within the state agencies charged with maintaining safety, mobility, and productivity of the transportation system. For all of these interested groups, this Concept of Operations provides an opportunity to share the vision of the North/West Passage *Clarus* Project Team and how *Clarus* System data can be incorporated with existing data and services to affect the use of road weather resources in a positive manner.

This Concept of Operations document is also intended for the weather service providers both engaged in surface transportation and those associated with general public weather services. These weather providers will accept the *Clarus* System data and assimilate it into their routine analyses and forecasts to support their respective clientele. Specific focus for this document is directed towards the surface transportation weather service provider community, as they are chiefly responsible for providing the road weather analysis and forecast information services presently used by the North/West Passage states, and who will be largely responsible for the generation of business-to-government services that is the heart of the *Clarus* Initiative. Just as the surface transportation weather service provider community was the primary end-user of the *Clarus* System in the original Federal Highway Administration *Clarus* Concept of Operations, so too are they with the North/West Passage *Clarus* Regional Demonstration Concept of Operations.

Their embracing of this Concept of Operations is crucial in the eventual conduct of a successful regional demonstration.

The final target audience for this document is the Federal Highway Administration (FHWA), specifically the FHWA Road Weather Management Program. This Concept of Operations is in response to their desire to demonstrate the efficacy of incorporating *Clarus* System data into a demonstration framework to substantiate the perceived utility of improved quality and accessibility of environmental sensor station (ESS) data, therefore supporting better road weather management strategies.

1.2 – Purpose for Implementing the Services

The multi-state *Clarus* demonstration across the North/West Passage states will provide a clear example of how an open and integrated approach to observational data management can be used to overcome road weather information deficiencies and improve road weather information products and services. The I-94/I-90 corridors span both extended rural settings as well as densely populated metropolitan areas that require knowledge of road and weather conditions in adjacent states. Such knowledge is critical for planning, conducting, and evaluating the effectiveness of activities such as winter road maintenance, weather-responsive traffic management, traveler information dissemination, safety management, and flood control.

The North/West Passage Team's Concept of Operations capitalizes upon the various opportunities that exist across the eight participating States to better incorporate ESS data within individual States and collaboratively across State borders. These activities are consistent with the goals of the North/West Passage Transportation Pooled-Fund Study (TPF-5(093)) and provide an existing framework for an eventual successful *Clarus* demonstration. Development of this Concept of Operations has included a synthesis of stakeholder user needs associated with various North/West Passage projects that can be enhanced with improved ESS data and products. These interstate projects encompass activities associated with enhanced traveler information systems, better usage of dynamic message signs, improvement of road condition reporting system applications, evolution of maintenance decision support systems, and support for more effective execution of road weather management strategies (e.g., advisories, control, and treatment). Each of these activities defines a stakeholder group incorporated in the Concept of Operations development. Tracking weather events across a multi-state region without regard for political boundaries affords the ability to take a proactive approach to both safety and travel time concerns. This feature is crucial to the interests of the North/West Passage Transportation Pooled-Fund Study.

The Concept of Operations envelops the relationships and expectations both within the *Clarus* system and between the *Clarus* system and the various agencies and stakeholders. The Concept of Operations presented herein supports the design and utilization of ESS data to better respond to:

1) Weather relevant to the roadway;
2) Applications utilizing spatial databases of relevant road characteristics including pavement composition, road slab depth, sub-grade composition, and underlying soil type;
3) Real-time road surface condition information; and,
4) Traveler information accessible under the operational conditions and requirements identified from the data use stakeholders.

This document presents a Concept of Operations tailored to the aggregated capabilities and operational needs of transportation system managers and users. It envisions a future state, through the use of stakeholder defined needs, in which there are information products, services, tools and decision support mechanisms that incorporate *Clarus*-enabled surface weather information.

The North/West Passage *Clarus* Regional Demonstration Concept of Operations is defined at a high level based on surface transportation weather information products and services that can be achieved. Overall, objectives include:

- Recognition of the operational characteristics needed to support its users and other stakeholders independent of technical issues needing a requirements analysis.
- A better understanding of goals by encouraging an open discussion among North/West Passage *Clarus* stakeholders to ensure that everyone has a common understanding of goals.
- Identification of the spectrum of personnel and skills needed to use, operate, and maintain the *Clarus*-related solution.
- The basis for planning future enhancements through the inclusion of a long-range view of the evolving *Clarus* system's capabilities.
- Participation of all North/West Passage *Clarus* stakeholders in the development of the concept of operations to permit the stakeholders to compare and coordinate activities and thereby resulting in an integrated view of the stakeholder organizations and missions as they relate to the mission of the system.

While the *Clarus* Initiative's primary focus is to facilitate safer travel, it also provides improved information for in-state and state-to-state highway maintenance activities, travelers, short- and long-haul trucking, power production facilities, event planning, construction, educational systems and others whom will come to rely on the higher resolution weather information for decision making. In time, each industry will develop their own feature requirements for the data, its timeliness, resolution, and specific parameters required within their industry.

For these reasons, the North/West Passage *Clarus* demonstration concept of operations provides multiple methods of ESS data usage. The systems interfacing with *Clarus* will range from real-time to post real-time across regions and include a number of industries. A general prioritization of performance is a firm requirement for surface transportation involving maintenance activities and transportation organizations.

1.3 – Overall Vision of the Clarus *Regional Demonstration Services*

User operation of *Clarus* in the North/West Passage Regional Demonstration will range from limited utilization to address short-term, event-specific situations to the acquisition of large quantities of daily data required for decision making processes associated with key aspects found within a specific transportation-related industry. The anticipated concepts to be developed for the demonstration address the ideals of the North/West Passage of utilizing effective methods for sharing, coordinating, and integrating traveler information across state borders. Focused efforts include using appropriate delivery systems, traveler information to support internal staff decision-making and supporting services used by the traveling public via 511, Dynamic Message Signs (DMS) and other systems.

Particular attention has been given to concepts that incorporate multi-state, multi-agency coordination. Efforts to gather stakeholder input highlighted the cross-jurisdictional needs, in addition to identifying the methods required to satisfy these needs.

1.4 – Goals and Objectives

Demonstrating an integrated multi-state road weather observation network and data management system will be a watershed moment in the efforts to reduce the impact of disruptive or catastrophic weather on road, transit, and rail users and operators. It will require a partnership of business and government stakeholders for successful facilitation. From a technical and institutional perspective, the North/West

Passage Transportation Pooled-Fund Study Program has an excellent understanding of the potential challenges and benefits of implementing such a system through *Clarus*.

The North/West Passage states have consistently been innovators of new technologies to collect and apply road weather information, and then disseminate that information to travelers. Whether these are from *in situ* mobile data collection platforms or from state-of-the-art remote sensing technologies, the Departments of Transportation (DOTs) of the North/West Passage are active in developing and deploying these technologies. Through *Clarus*, it will be possible to provide these data to a broader business and government community, thereby enabling improved forecasting tools to address road weather information needs.

Objectives of this project are:

(1) To demonstrate that the contribution of each State's Environmental Sensor Station data to the *Clarus* system functions as designed;
(2) To enable proactive transportation system management through utilization of the *Clarus* system; and,
(3) To provide an environment private sector service providers can use to create new and improved products benefitting the public, academia and other private industries.

To accomplish these objectives, the North/West Passage Team's Concept of Operations capitalizes upon the various opportunities existing across the eight participating States to better incorporate ESS data within individual and collaboratively across State borders. These activities are consistent with the goals of the North/West Passage Transportation Pooled-Fund Study and provide an existing framework for an eventual successful *Clarus* demonstration. The Concept of Operations supports the broader *Clarus* objective to design and utilize ESS data to better respond to:

1) Weather relevant to the roadway;
2) Applications utilizing spatial databases of relevant road characteristics including pavement composition, road slab depth, sub-grade composition, and underlying soil type;
3) Real-time road surface condition information; and,
4) Traffic information accessible under the operational conditions and requirements identified from the data use stakeholders.

1.5 – Assumptions and Constraints

This Concept of Operations is a plan tailored to the aggregated capabilities and operational needs of transportation system managers and users. The Concept of Operations is assumed to be part of a broader systems engineering process outlined in Figure 1 where the elements within the Concept of Operations envisions a realistic future state in which there are information products, services, tools, and decision support mechanisms that incorporate *Clarus*-enabled surface weather information (3).

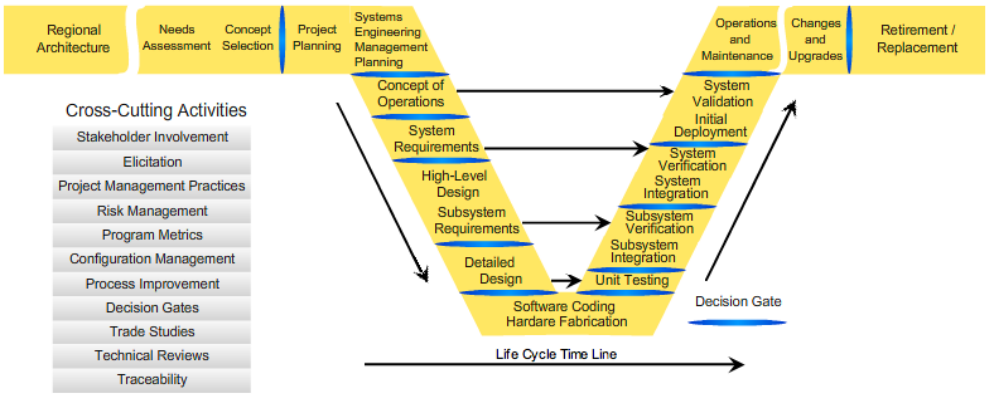

Figure 1. The Systems Engineering Process associated with the development of an Intelligent Transportation System deployment (3).

A regional concept for operations requires deliberate, sustained collaboration among transportation operators and others who recognize the opportunity to improve system performance in their region. The participants will face a number of significant challenges and opportunities as they work together to achieve mutual objectives. Among these challenges and opportunities are:

- **Identifying and defining the basis for collaboration**.

  For the North/West Passage Transportation Pooled Fund, collaboration will come as a natural outgrowth of existing relationships fostered through past and current projects that brought the participating state agencies together. These collaborative activities will likely continue to demonstrate the benefits of working together and provide the foundation for recognizing areas where the collaboration needs to be sustained.

- **Awareness of multi-state operations requirements of system users.**

  Most agency functions within each state are focused upon providing systems and services required of the taxpayers within their respective states. This leads decision makers to typically view their responsibilities from the perspective of their individual state agencies. To achieve a regional demonstration goal of multi-state exchange of information and services will require transportation managers and operators to view the benefit and/or consequences of their actions and decisions from a perspective viewed from outside their jurisdiction. Thinking regionally will require a top-down view by management of the importance of providing services that leads to cooperation with out-of-state peer organizations on day-to-day activities and coordination.

- **Attracting the business community to collaborate with their peers to provide regional services**

  The service providers of existing and future services to individual state transportation agencies largely provide stove-piped services that have limited interoperability and interface capability with other service providers. The capability of this sector to agree to participate in the regional demonstration, which will require investment of their time and likely alteration of their methods and/or interfaces to their data, will present a challenge that must be considered during the final demonstration design.

- **Determining what can reasonably be done over a two-year demonstration period.**

The *Clarus* regional demonstration is a prototypical activity intended to construct and exercise new functions and services that designed to validate the value of a quality checked and centrally managed collection of environmental sensor station observations. The scope of potential new functions and services must be regarded realistically as to what can be achieved within a one-year build-out and a one-year demonstration. The establishment of a realistic demonstration concept must include those external interfaces from the business community who will be tasked with providing much of the development and delivery of these new services and functions.

- **Understanding the fiscal and staffing constraints associated with sustainability of services and functions beyond the *Clarus* regional demonstration**.

  The performance of a regional demonstration involving new services and functions that are expected to result in increased safety, mobility, and productivity will establish expectation levels by end-users in state agencies and the broader public and commercial user community. Sustaining the delivery of these new services and functions beyond a successfully federal-funded demonstration project will present challenges to state agencies. Equally significant will be the availability of appropriate staffing to support on-going future activities.

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Section 3. Background

3.1 – Operational Description of the Current Situation

The North/West Passage encompasses the eight states along I-90/I-94 (Figure 2) from Wisconsin to Washington. In these states, there are numerous systems for collecting, processing and integrating traveler and road maintenance information, and delivering the information to users. However, this information is not readily shared across state borders, including the Environmental Sensor Station data, which is fundamental to the *Clarus* system.

Figure 2. The routes of Interstate 94 and Interstate 90 as they extend across the eight states that comprise the North/West Passage Transportation Pooled-Fund Study.

Each of the North/West Passage states have a demonstrated history in the use of road weather information to support their internal decision making and provision of road weather information to users of the transportation system. A summary of the Intelligent Transportation System (ITS) deployment statistics compiled by the Federal Highway Administration (Table 1) demonstrates this historical utilization (4).

Table 1. FHWA Surface transportation weather 2006 ITS deployment statistics

Note: The states of Idaho and Wyoming did not file statistics for 2006 and are not represented

Surveillance, Monitoring and Prediction	Minnesota	Montana	North Dakota	Washington	Wisconsin	South Dakota
In-pavement or road surface sensors to track pavement conditions	X	X	X	X	X	X
Deploy ESS in rural areas	X	X	X	X	X	X
Deploy sensors to monitor water levels on roadways				X		X
Traffic Control						
Disseminate weather information to travelers using DMS	X	X		X	X	X
Disseminate weather information to travelers using HAR		X		X		

Disseminate weather information to travelers using Internet web site	X	X	X	X	X	X
Employ variable speed limits in response to weather				X		
Traffic signal timing in response to weather						
Deploy ITS technologies to manage traffic diversions in response to weather-related road closures	X	X		X	X	X
Employ ITS sensors and information dissemination technologies to determine restrictions during inclement weather	X	X	X	X	X	X
Response and Treatment						
Deploy automatic bridge anti-icing systems	X		X	X	X	
Deploy snow plows with AVL, communications and sensor to monitor treatment	X	X	X	X	X	X
Integration						
Archive weather warnings						X
Public safety provides warnings	X	X		X		X
State police provides warnings	X			X		X
Local agencies provides warnings	X					X
Traffic management provides warnings	X			X	X	X
Incident management provides warnings	X			X		
Traveler information provides warnings	X	X			X	X
Information service provides warnings				X		
Tourism boards provides warnings						
Other state warnings		X				
Archive weather forecasts						X
Public safety provides forecasts	X					X
State police provides forecasts	X			X		X
Local agencies provides forecasts						X
Traffic management provides forecasts	X			X	X	X
Incident management provides forecasts	X			X		
Traveler information provides forecasts		X		X	X	X
Information service provides forecasts				X		
Tourism boards provide forecasts						
Other state forecasts		X				

The road weather related activities that could be affected and enhanced by the incorporation of data from the *Clarus* System are identified below for each state.

Wisconsin: Currently, the state is using a road weather reporting system that was developed for use by the state. While no 511 system currently exists, a recent Request For Proposal for a 511 system with an integrated reporting system is now under development. The design of the system will provide road weather and road related weather information for key routes across the state. Plans currently include integration with Illinois traveler information and accident information provided by Highway Patrol databases. While no road weather information is planned for the system, National Weather Service forecasts are planned for inclusion. It is unknown at this point if a website will be part of an integrated system associated with the new 511 system. Highway Advisory Radio (HAR) and DMS systems are

currently used across the state. Winter road maintenance is performed at the county level on behalf of the state DOT. Wisconsin contracts with a surface transportation weather service provider (STWSP) to provide forecasts and storm alerts to each county manager in the state. The propensity of weather moving in from the west makes access to the ESS data from neighboring states of Minnesota and Iowa critical for operations, particularly in counties near those border states. Data from those states is currently provided to WisDOT and the counties through the STWSP thanks to a cooperative agreement with the Minnesota and Iowa Departments of Transportation.

Minnesota: Minnesota currently employs the Condition Acquisition Reporting System (CARS) for the collection of road and weather conditions. CARS allows conditions across the state to be entered into a single integrated database. This information is then processed to update a map-based website, statewide 511, and can be used to update Dynamic Message Signs (DMS) across the state. While road weather is not integrated into this reporting system, 511 does supply National Weather Service forecasts for travelers. Specific road condition forecasting is not part of the current system. While the CARS data is provided to western states adjoining Minnesota for integration into their respective 511 systems, Road Weather Information System (RWIS) data is not provided directly to any adjoining state. Additionally, 511 road condition and weather information from adjoining states is not integrated into CARS or the Minnesota 511 system at this time. Minnesota is a member of the Pooled Fund Study Maintenance Decision Support System (PFS MDSS). Through this system, maintenance officials are provided maintenance treatment recommendations based on past, present, and future road conditions, weather, and maintenance actions.

North Dakota: North Dakota currently uses a road weather reporting system developed specifically for the state DOT decades ago. There is no integration of road conditions as they relate to construction, accidents, or special events. This system is designed to centralize all reporting of road weather conditions across the state through a highly human intensive manual operation affecting the timeliness of the information. The 511 system does integrate road weather information as provided from Montana, South Dakota, and Minnesota. The 511 system does provide private road weather forecasts by route, but does not include road surface condition forecasts. The RWIS network across the state is integrated into the road weather forecasting for each route. DMS systems are used to inform travelers in a few areas, with one that works in concert with Minnesota. The reporting system also provides information to a website that reports road conditions and spring load conditions, while the website and 511 acquires construction information from a separate database. North Dakota is a member of the PFS MDSS.

South Dakota: South Dakota is currently employing the Integrated Roadway Information System (IRIS) to allow the decentralized reporting of road conditions, accidents, events, and construction and is integrated into a permitting system to supply information for permit route charting. This system is designed for the administration of a variety of security levels that allows different areas of the state to report road weather information restricted to its area of responsibility, while allowing a view of the entire state network. The 511 system does integrate road weather information of adjoining states as provided by Montana, North Dakota, Wyoming, Nebraska, and Minnesota. The 511 system does provide private road weather forecasts by route, but does not include road surface condition forecasts. This system allows for alerts including general transportation, homeland security, and Amber Alerts. The RWIS network across the state is integrated into the road weather forecasting for each route. DMS systems are used to also inform travelers. A website is provided within IRIS to provide online access to the same information available on 511. South Dakota operates as the project lead for the PFS MDSS.

Wyoming: Wyoming's current road condition reporting system is represented by a state developed system that currently is used for seasonal road weather reporting. It is designed to provide reported road

conditions and road related weather information. Construction, accidents, and events reside in separate databases and have yet to be integrated into the current 511 system. The system allows for alerts including general transportation, homeland security, and Amber Alerts. The 511 system does integrate road weather information of the adjoining states South Dakota, Montana, and Nebraska. The 511 system does provide private road weather forecasts by route, but does not include road surface condition forecasts. A website provides integrated information from the current databases that include road conditions and road related weather information. Wyoming joined the PFS MDSS in 2005.

Montana: Montana's reporting system is a decentralized state designed system that allows areas or districts to report road conditions and road weather related information. Additionally, construction, accidents, events, and some facility information is also provided to the 511 system. The system allows for alerts including general transportation, homeland security, and Amber Alerts. The 511 system does integrate road weather information of the adjoining states Wyoming, South Dakota, and North Dakota. The 511 system does provide private road weather forecasts by route, but does not include road surface condition forecasts. A website is not currently provided information as presented on the 511 system; however, this feature is currently under development. DMS systems are used across the state to provide information to travelers.

Idaho: The CARS system is currently used to report and provide 511 systems within the State of Idaho. While this system allows for a decentralized approach to reporting road conditions, construction, accidents, and events, it does not provide road weather information or road related weather information; however, National Weather Service forecasts are included. CARS allows conditions across the state to be entered into a single integrated database. This information is then processed to update a map-based website, statewide 511, and can be used to update DMS across the state. There is no adjoining states information integrated within the 511 system. However, Road weather information systems do provide information over DMS systems along I-84 that reports visibility problems.

Washington: Using a state developed reporting system, Washington provides road weather conditions and traffic information across key routes throughout the state. This system integrates road conditions, traffic, and accidents and is provided over a 511 system. Road weather information is provided through the system with a forecasted element to provide travelers with future view of expected road conditions. A website provides access to this information and includes access cameras along specific routes with urban areas. Ferry, National Weather Service, and construction information is included on both a website and 511. DMS systems are currently used, while no adjoining state 511 information is integrated within the available systems.

3.2 – Limitations of the Current Situation

With the different levels of use and integration of road weather and road related weather conditions across the North/West Passage States, opportunities exist for improvement in the management, use, and integration of available data that can offer enhancements to existing and planned systems. This integration would offer further reliable enhancements by the development of *Clarus* through its quality control of this data before integration, ensuring a higher degree of reliability and timeliness. Planning exists only when information about current and expected conditions is readily available. This holds true both for maintaining and for using the highway system. Integration between states with road weather data can and will generate a level of information for planning both trips and maintenance activities that is not presently available.

Application of road weather information to route-specific forecasted road weather and the addition of road condition forecasting would offer each individual state a greater degree of operational support, while

greatly enhancing the available information for the traveling public, both private and commercial. The integration of this data coupled with reported road conditions across state lines stands to create a travel information network that could be expected to and would increase traveler safety, traffic mobility, and managed service utilization along specific routes. Availability of road weather data to weather service providers will promote the development of forecast systems and models that will enable greater accuracy and reliability when dealing with local micro-climates. This knowledge will offer the opportunity to produce route-specific road weather and road condition forecasts that are rarely available across the region today.

The true measure of the success of this application does not lie within the integration of the data itself, but the management of the road network, traffic, and increased travel safety for the traveling public. Additional successful evidence will reside within the separate, but equally important, opportunity for improved management of equipment, personnel, and materials for the maintenance of the highway network itself. These two areas, when measured properly, would provide the evidence that an opportunity to plan across state lines can and will provide an increased flexibility in scheduling, material management and savings.

3.3 – Justification for and Nature of Changes

Drawing upon information from the summary of limitations that exist within the present regional activities of the North/West Passage utilization of road weather and from a review of statewide ITS architectures, the North/West Passage Transportation Pooled Fund planning documents, and from the results of user needs, a series of service functions are needed to improve the current situation and to provide for improvements in transportation safety, mobility, and support for broader productivity.

Although the focus of the *Clarus* regional demonstration is meant to emphasize how *Clarus* System data can be used to improve road weather utilization, implementing methods to accomplish these advancements requires adjustments and improvements in various aspects of the transportation system and utilization through improved application of weather data and information within a roadway environment. The need for these changes relates to the awareness of the growing importance of making informed and proper decisions pertaining to maintenance activities and support for decision-making and travel planning. To effectively accomplish the vision of North/West Passage and implement changes to the current situation, it is necessary to support the efforts of providing assistance to agencies and programs that promote traveler safety through maintenance, operations, and traffic and emergency management activities.

Specific desired changes to support these ideals are the addition of the following functional capabilities:

- Improved interstate advisory and control strategy coordination and communications;
- Enhanced weather content for 511 information systems;
- Availability of regional road weather and road condition information including a predictive component of both road weather and road conditions; and,
- Provision of services supporting automated alert and notification of road weather-related elements and conditions.

The justification of these desired changes was established through a comprehensive user needs analysis involving face-to-face stakeholder meetings in each North/West Passage state and a web-based survey that solicited stakeholder input from system users across all participating states. Given the geographic location of the eight North/West Passage states along the northern tier of the United States, the designation of winter weather hazards as the dominant weather interest was expected (Figure 3). The principal interests in road weather information for each stakeholder group were strikingly similar. This

reflected the inherent interest of all groups to promote a safe travel capability and to maximize the movement along the highway system.

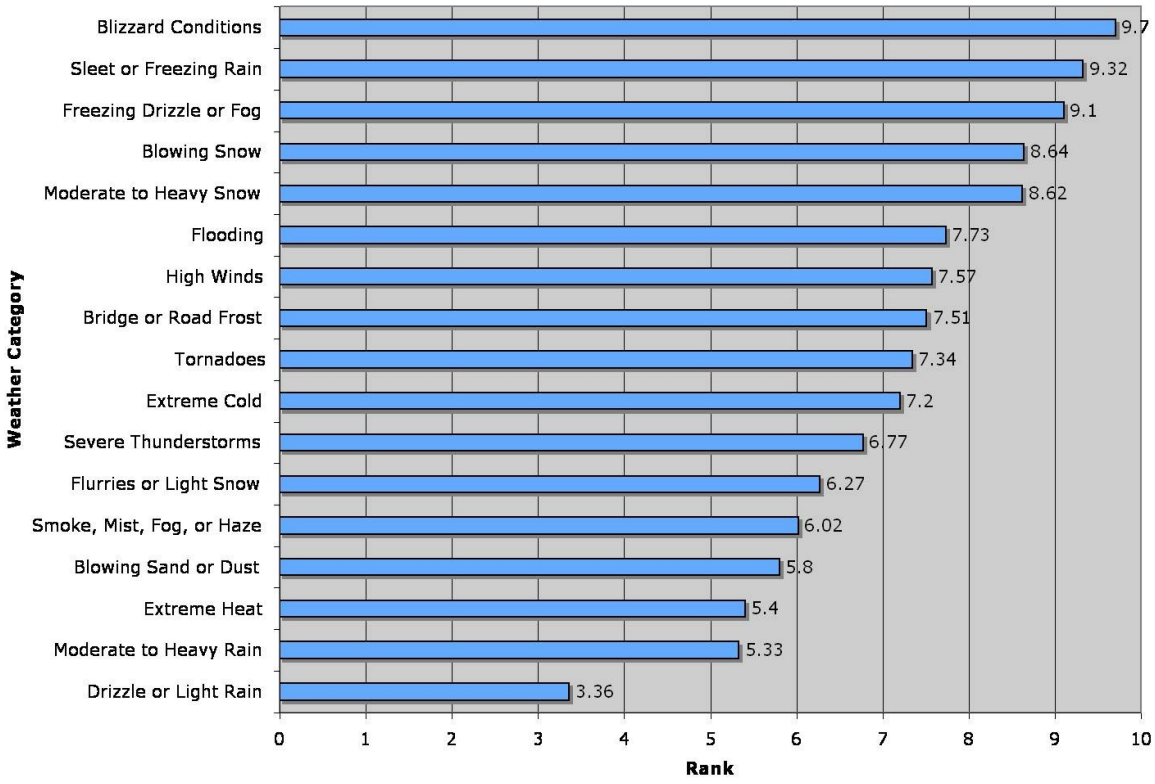

Figure 3. Overall averages for all User Groups weather concerns. Sample size of 1,566 completed responses.

User needs found represent a composite of findings from a synthesis of the web-based surveys of stakeholders, composites of the site interviews conducted within each North/West Passage state, consideration of existing state and regional ITS architectures, and the goals and ideals that serve as the foundation for the North/West Passage Transportation Pooled Fund project. Generally, the North/West Passage states and the surveyed stakeholders agree that having improved site-specific and broader road network weather and road conditions is a need. Whether this information is to be used by state agencies for improved implementation of advisory, control, and treatment road weather management strategies or by travelers for better-informed travel decision-making, a synergy exists in the user needs. Specific findings from the user needs analysis include:

- The World Wide Web is the primary information access method by agency and non-agency stakeholders for in-state and cross-state information related to road conditions and weather.
- Information alerts to changing conditions, particularly road conditions, would be an acceptable method for providing support to travel planning and decision-making
- Travelers when making winter travel plans spanning long distances seek multi-state information. This information includes road condition, imposed controls and observed/forecasted weather
- The demand for multi-state road condition and weather information by state agencies is not as high of a demand as it is for travelers although state agency interest is maximized along borders.
- If available, forecasted road conditions would be of interest to the traveling public

- The lack of timely, reliable, accurate observations (particularly from ESS) is a significant stigma attached to current road weather observations
- The lack of confidence in weather and road condition forecasts by maintenance personnel is a hindrance in decision-making
- Travelers (general public and CVO) interest exists in improved travel go/no go decision support
- The awareness of 511 as a primary source of travel information remains below other less travel focused information sources. Improved decision support content and better information reliability would significantly increase the utilization and awareness of 511.
- In-vehicle information delivery systems are expected to be a major technology advancement in travel decision support
- Web map displays of road weather / road condition information are stove-piped to individual states and do not do provide adequate integration in support of regional traveler support
- Multi-state weather / road condition web portals would greatly enhance the exchange of information across states and support stakeholder use.
- Assessment of weather service provider responses from the National Weather Service suggest that *Clarus* quality checked data is of an unknown benefit due to that agency's existing quality checking methods.
- The availability of ESS data is a concern to personnel in state transportation agencies both from the spatial and temporal availability of the data.
- Site-specific weather information along the roadway is of significant interest to both the operators and users of the highway system and the reliance on this data is limited only by the availability, accessibility, and quality of the information.

User Need: Interstate Advisory and Control Strategy Communication Coordination
Situations were cited by state department of transportation operations personnel where closing a road in a neighboring state results in significant impacts on the transportation actions in their state, such as long lines of vehicles waiting for roads to re-open or travelers needing lodging. Having information in advance or at the time of imposition of these controls would provide an effective means of both informing the traveling public of travel delays or need for detours as well as improve the maintenance coordination across state borders.

User Need: Implementation of a Fine-Resolution, Multi-State Road Network Road Condition/Road Weather Forecast System
Complementing the need for advisory and control actions in adjacent states is the need for more reliable and spatially specific road condition information. This is a challenge for the present ESS to detect and actual road conditions are more often observed during route patrols. Having better information is not just limited to the observed conditions, but also to forecast conditions. The latter becomes crucial in planning activities for both state DOTs and travels. The availability of this road condition information can be communicated. For travelers planning to traverse distances beyond one state or even an entire Interstate corridor, there is a need to have reliable information on current and future road and weather conditions for planning purposes. The present dependence is upon reported road conditions and relating these to anticipated future weather conditions. For CVO long-haul traffic, where dispatch decisions on one end of a corridor must take into consideration what will be transpiring as the vehicle approaches its destination, much is left to chance during periods of inclement weather. For all travelers, the capability of making go/no go decisions during winter is left to chance and reduces traveler confidence on safe travel. This calls for greater synthesis of road weather forecast information with corresponding anticipated (forecast) road conditions.

User Need: Providing Enhanced Road Weather Content for 511 Information Systems
Present 511 systems across the North/West Passage states have limited capabilities in providing road condition information and access to road weather and road condition information across borders. Providing mechanisms to enhance the site-specific road weather content, including the providing of future road condition data to traveler information would provide a framework enhancing traveler decision support along highway corridors spanning multiple states.

User Need: Development of an Automated Alert and Notification System
The availability of wireless and cellular messaging provides the opportunity for proactive notification of changing road and weather conditions to support maintenance operations and traveler decision-making activities. Such notifications should be incorporated to provide a user-configurable road condition / weather forecasting system alert and notification capability that satisfies the user's temporal and place-based requirements for information supporting their decision making. A web-based user subscription to the alert system would permit users to configure the details of information included in the notifications.

Section 4. Overview of *Clarus* Regional Demonstration Services

The North/West Passage *Clarus* Regional Demonstration will involve a mixture of business-to-government and government-to-government services. The following provides a high-level overview of the functionality of these services without specifying design details or technology-specific solutions.

4.1 – Boundaries for Clarus *Regional Demonstration Services*

The North/West Passage *Clarus* Regional Demonstration is composed of the functions and services necessary to enable the North/West Passage states to better realize the benefits of quality checked, regionally available ESS data both for their internal operational decision making and the provision of enhanced information to users of the transportation system. The North/West Passage *Clarus* Regional Demonstration is envisioned as a business-to-government and government-to-government collaboration to provide a comprehensive, systematic, and dynamic means for utilizing ESS data. Figure 4 provides a high-level description of the physical and functional boundaries of the business-to-government and government-to-government services.

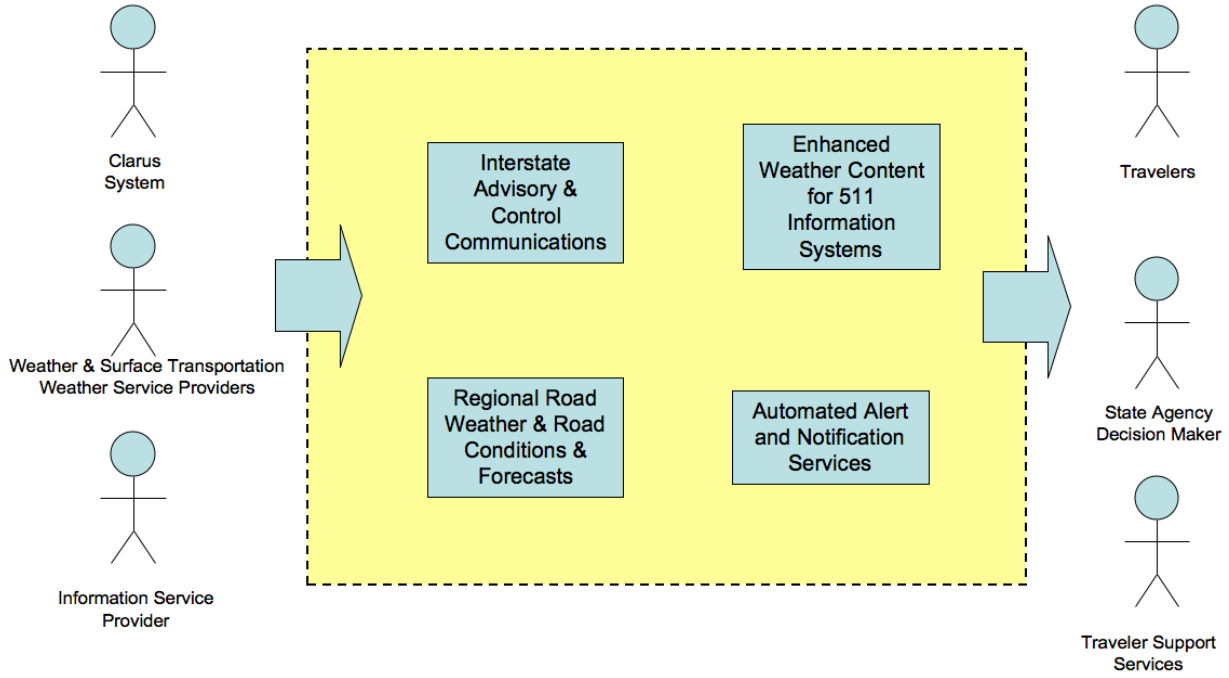

Figure 4. North/West Passage *Clarus* Regional Demonstration System Boundaries and External Interfaces.

The services include the functional systems:

- **Interstate Advisory and Control Communications** - The interstate advisory and control strategy coordination and communications function explores the utilization of a coordinated exchange of active and anticipated advisories and controls across the North/West Passage to improve interstate transportation efficiencies;

- **Enhanced Weather Content for 511 Information Systems** - The enhanced weather content for 511 information system function extends the availability of route-specific road weather information for 511 to provide improved, more reliable place-based road weather data along multi-state highway corridors;
- **Regional Road Weather & Road Conditions and Forecasts** - The regional road condition/road weather reporting and forecasting system function explores the implementation of a database and distribution system whereby road condition information presently collected in individual states is aggregated and made more broadly available to stakeholders across the entire North/West Passage region and beyond including the incorporation of predictive components of the pavement/driving conditions; and,
- **Automated Alert and Notification System** - The automated alert and notification system function explores the use of the concept of information push technologies to provide surface transportation weather stakeholders with information in a proactive manner.

The external actors describe the providers of information into the various internal functions (left side of Figure 4) and those who are receptors of information products and services benefiting from the *Clarus* System data (right side of Figure 4).

4.2 – Stakeholder Roles and Responsibilities

The original *Clarus* ConOps identified stakeholders in a priority order from 1st order through 4th order. This distinction expressed these orders as:

- State DOT decision-makers - 1st order
- Surface Transportation Weather Service Providers -1st order
- Weather Service Providers - 2nd order
- Research Community - 3rd order
- Non-surface transportation weather interests - 4th order

After a review of the interests within the North/West Passage, this ranking was modified to include two additional stakeholder groups – Travelers and Non-Transportation State Decision Makers. The former group consists of both the general traveling public and commercial vehicle operators. All of the North/West Passage states have existing programs, such as 511, to provide support for this stakeholder group and are committed to sustaining/improving this support. In addition, all of the North/West Passage states either work or closely collaborate with public safety and emergency management agencies in their states. While both of these stakeholder groups could fall within the 4th order listed above, it was felt that these groups are significant to the activities of the North/West Passage states and deserve a higher degree of attention. Both are considered as 1st order in significance.

4.3 – External Interfaces

The services to support the North/West Passage *Clarus* Regional Demonstration will in large part be provided by the external entities. These external entities will be predominantly from the surface transportation weather service provider community with additional services provided by the weather service provider community and information service providers. Combined, the first two providers constitute the principle user community for the *Clarus* System as described in the FHWA *Clarus* Concept of Operations (5). Where provided by the private sector, these external interfaces provide a business-to-government interface. However, the National Weather Service is a source of weather information to support various traveler information systems and the decision-making for advisory and control road weather management strategies. These external interfaces constitute a government-to-government interface. Both of these entities provide the majority of their service support via electronic delivery of

information, most notably using the web-based services over the Internet. For support of road condition reporting and 511 traveler information services, the external interfaces expand to include information service providers who are not within the weather community. The information service providers support telecommunications, database accessed traveler information, and the accumulation of road condition reporting. When combined with the weather and surface transportation weather service providers, the information service providers become a conduit for the transmittal of weather information to users of advanced traveler information systems.

Few standards are formalized for the external interfaces. However, the use of recommendations published by the World Wide Web Consortium (W3C) encourages style sheets and markup languages such as HTML, XHTML, SVG, and XForms (6). The growth in the use of the extensible markup language (XML) as a mechanism for the exchange of data is another standard that is becoming more of an accepted practice. It would be expected that a combination of the above recommendations and standards would be incorporated in the Regional Demonstration to facilitate a common communications method of information and data. Other anticipated *de facto* standards and that are presently in use for transmittal of data are the use of comma separate variables, such as that used by the *Clarus* System for distribution of its data, and the network common data format (NetCDF) that is widely used within the scientific community for data exchange. When data exchanges are made between database systems, the use of structured query language (SQL) standards as adopted by the International Organization for Standards (ISO) are anticipated. These SQL standards support the use of various proprietary database systems and support interoperability between databases that will be necessary (7).

The traveler information standards to be used will come from existing standards used by the North/West Passage states within their 511 systems. These standards include primarily the Traffic Management Data Dictionary (TMDD) and associated message sets for external traffic management center communications (8).

4.4 – Functional Architecture

The development of the North/West Passage *Clarus* Regional Demonstration is a high-level overview stating the desired activities and outcomes to satisfy the needs identified through a thorough review of stakeholder needs. The process followed is consistent to methods outlined by the FHWA "Systems Engineering Guidebook for ITS" (9) in identifying in a non-technical method the concensus of multiple stakeholders views. The functional architecture is constructed from the four highest priority user needs from a set of user needs determined through a user needs discovery effort. These user needs have been combined into a consolidated package where the user needs complement one another. This synergistic relationship is highlighted in Figure 5 showing a high-level description of the interrelationships among the key functional subsystems of the business-to-government and government-to-government services.

The reception of inputs to the architecture represents terminators to the systems where the received data constitute actions supplied by the external interfaces to the architecture i.e. the weather and surface transportation weather service provider communities, transportation agencies contributing their data and information supporting a regional architecture, and end-user inputs that define the configuration of the description of desired alert and notification requirements. Beneath the depicted high-level description of the functional architecture are the system level details that define the specific design elements that must yet be designed such that they satisfy the functional requirements of the demonstration.

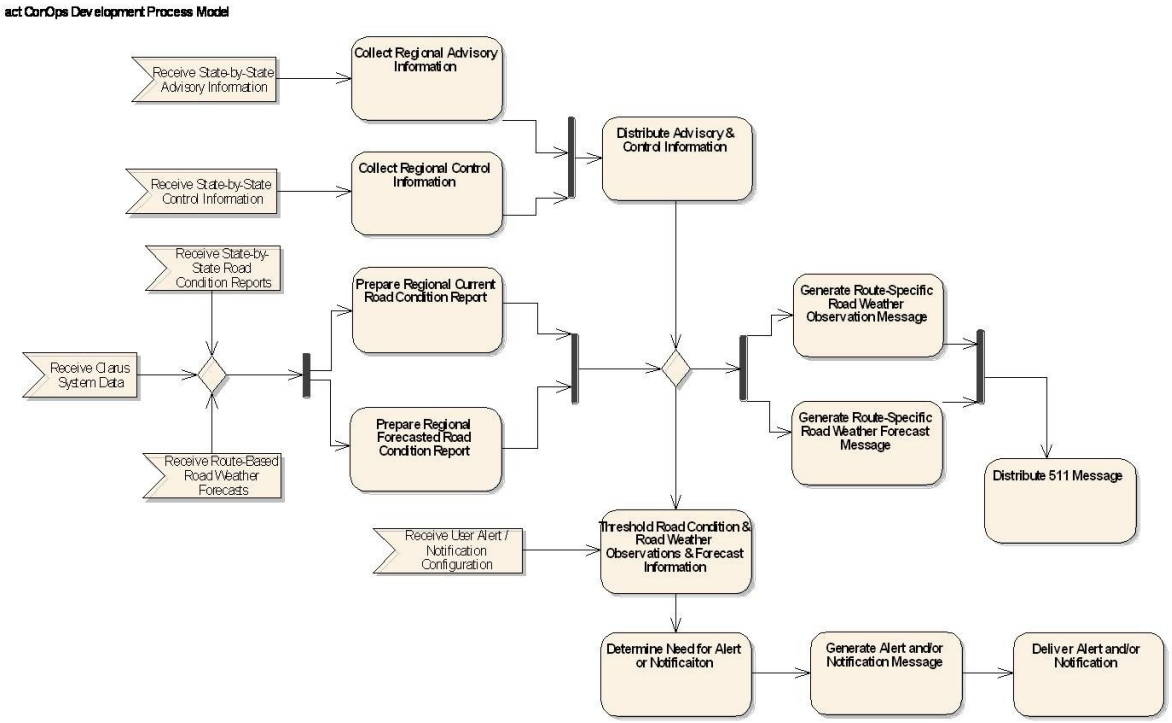

Figure 5. Functional Area Diagram describing the business processes associated with the functional architecture of the North/West Passage *Clarus* Regional Demonstration.

4.5 – Capabilities and Functions

The major business-to-government service functions within the North/West Passage presently provide a significant foundation and experience to support enhancements within the *Clarus* Regional Demonstration. These existing capabilities and functions will provide data and information content to support the four distinct packages constituting the demonstration. Through the incorporation of *Clarus'* ESS data and quality control flags, the proposed packages will enhance and extend the existing capabilities through regional networking of data and information for further dissemination or the provision of new service functions. The present major business-to-government capabilities and functions that will be incorporated include:

Road weather forecasting: Road weather forecasting provides mesoscale weather forecasting tailored to meet the needs of the surface transportation decision-making community. Focused primarily on supporting winter maintenance actions associated with snow and ice control, these forecast services provide informative descriptions of future pavement conditions and weather conditions within the roadway environment. Various surface transportation weather service providers supply the North/West Passage states with weather information, often as a web-based information resource providing immediate availability to surface transportation users and decision-makers. The addition of *Clarus* data from across the North/West Passage region and beyond permit greater availability of roadway-based weather observations from which most road weather forecasts are based. The availability of these data to the surface transportation weather service provider facilitates improved forecasting and methods of validating their forecasts. This in turn will provide consumers of the resulting road weather forecasts an enhanced source of information for decision-making.

511 travel information services: Advanced traveler information systems are a major source of road weather and road condition data across the North/West Passage states. These systems generally function autonomously from each other with most states having the capability of accessing information across adjacent state borders. The systems are primarily contracted services providing a business-to-government framework for extending the traveler information resources with the addition of *Clarus* and *Clarus* derived data. The addition of *Clarus* ESS data provides greater site-specific road weather information along the route of travel. States located in the North/West Passage can feel significant road weather impacts on their travelers, and understand the need to collaborate with surrounding states. Travelers are frequently impacted by closures not only within a state, but also often in neighboring states. Additional data needs can be assisted through *Clarus* ESS information and communication between the states.

Maintenance decision support systems: Winter road maintenance relies heavily on approaching weather. The improvement in the winter road maintenance decision-making through the use of maintenance decision support systems is a major emphasis for a majority of the North/West Passage states. Services provided by several businesses yield a variety of maintenance decision support system methods and presents an opportunity to utilize *Clarus* data to enhance both the in-state and regional decision-making process. As weather often moves from west-to-east across the North/West passage states, their orientation makes ESS data from neighboring states a critical component for operations. This is particularly important for counties that border these states. Having access to *Clarus* data across the region within a maintenance decsion support system can be regarded as a valuable asset for winter weather maintenance. In addition, having the *Clarus* quality-controlled data will allow for better analyzation of current road conditions, which is crucial for the deployment of a successful maintenance decision support system. *Clarus* can only make the integration of this information between states seamless in the future.

Road road condition services: Weather systems traversing the region defined by the North/West Passage states often move rapidly and can impact multiple states with dramatic weather conditions requiring actions from each of the road weather management strategies in each affected state. Often during these extreme winter weather events the impact of state agencies, e.g. transportation, emergency management, public safety, etc. result in the need for information extending beyond the state boundaries of each state. The North/West Passage states have individually adopted various business-to-government road condition reporting systems to provide for an effective collection and dissemination of statewide construction, incident, and road condition information. These business-to-government services are envisioned to be a solid framework to enhance the awareness of the regional road conditions including the use of *Clarus* data to expand the real-time knowledge of the state of the road. This will provide an effective mechanism whereby states may share information with adjacent states to support efficient responses to road weather-related conditions.

The business-to-government services above are but a start in realizing the benefits of *Clarus* data to improved mobility, safety, and productivity across the North/West Passage Region. The presence of these functions and capabilities are a result of a long-term positive relationship that has existed between the departments of transportation and the private and academic sectors found across the North/West Passage Region.

4.6 – Service Performance

Weather and road conditions change rapidly during winter conditions that occur across the region encompassing the North/West Passage states. To account for these rapid changes in weather and road conditions, the frequency of road weather forecast generation has increased in the past decade from once

or twice per day to as frequent as hourly by some surface transportation weather service providers. To support this increase in frequency of road weather information generation, the frequency of input observations must also increase. Hence, the throughput required to accommodate these needs by the surface transportation weather service providers is measured in at most one-hour intervals in data availability. As the processes used to accumulate observations are computer-based and frequently execute at regular intervals, the data availability must be coupled with a high-speed communications link to support immediate transfers of *Clarus* System data to the providers of weather services. This speed is also imperative for the service providers incorporating ESS data into their information streams, such as 511 information systems and for the state agencies directly viewing the *Clarus*-provided ESS data. The volume of ESS data provided by the *Clarus* System is minor when compared to most weather observation data, but for entities such as information service providers who are not accustomed to these levels of data flows, there must be adequate capacity to manage thousands of weather observations per hour. This includes having a capacity to permit an effective reception/transmission of data and the computer-based tools to manage the data storage. The most crucial performance requirement will be the accuracy of the data. The service performance will depend greatly on the ability to properly utilize the quality checking information provided by the *Clarus* System to identify low quality, inaccurate data and restrict the use of these data in development and delivery of output services to agency and general consumers.

Section 5. Operational and Support Environment

The purpose of this section is to ensure that stakeholders consider, at an early stage, changes to existing physical hardware and equipment, as well as new maintenance and support functions that may be required to support the services. The description excludes details of specific technologies or solutions and focuses instead on the anticipated environment for the business-to-government services.

5.1 – Physical Environment and Facilities

The physical environment for the conduct of the North/West Passage *Clarus* Regional Demonstration will span the National Highway System of each of the eight North/West Passage Transportation Pooled Fund participating states. Emphasis is intended to reside with the Interstate 90 and Interstate 94 corridors, but the interstate travel and impacts of this travel across state borders on non-Interstate highways strongly suggests the inclusion of this broader road network. This is expected to present minimal impact to the demonstration efforts, as the framework required to support the Interstate corridors should be easily extensible to the non-Interstate corridors. Further, many of the systems and facilities anticipated to be utilized in the demonstration presently support this broad context i.e. statewide 511 traveler information systems.

The facilities anticipated for the demonstration will draw significantly from existing infrastructure being used by the state departments of transportation. This includes the use of private sector services and facilities that provide much of the existing services associated with traveler information and maintenance weather support.

5.2 – Hardware

The final architecture of the system hardware will depend upon the degree of integration of *Clarus* data into existing and planned ITS systems. Servers for storage of data, program operations systems and archival servers will be required with redundant support system to ensure 24/7/365 operations and availability. New hardware at each operator location designed to manage the interface, query, and application of the data will be required. Policy and procedures of operation for *Clarus* referencing current versus historical data will further outline the specific operational requirements of these servers. Additionally, middleware should be implemented for queries both internal and external to minimize changes necessary to the database hardware as new requirements, data, or applications are developed for *Clarus* data.

5.3 – Software

A number of software products will need to be developed to facilitate the management and dissemination of both quality controlled and raw data from multiple ESS systems across the participating states. Ingest programs will be developed to facilitate capture of data from different systems (i.e., ESS data, road conditions data, etc.). Beginning at the user, a graphical user interface with GIS referencing will be needed to display the data with the query programs that interface with the middleware to acquire data from other states. Software development activities will include a user interface designed to allow the user to parse and develop specific data elements for inclusion into the other existing and planned ITS systems (DMS, RCRS, HAR, 511, etc.). Programs to automatically archive data elements from all systems after a specific period will be required. Additionally, watchdog programs should be included to alert system management personnel of problems when they occur to facilitate corrective action at the onset.

5.4 – Personnel

Personnel within the *Clarus* operations will require specific database, hardware, network, and programming experience to manage interfaces between the databases, archival database systems, middleware, and graphic user interface. Each state system should be able to manage their respective operations with a single dedicated ESS manager that can also assist users with their state with necessary interface problems within their own areas. This would include maintaining ESS systems around the state, managing the data flow to the *Clarus* database, and working with other state agencies or departments that access the data for operations (TOC/TMC, 511, DMS, etc.). This responsibility is expected to require 40 plus hours per week and include ESS management and maintenance experience to train new users within the state to interface with *Clarus,* as well as manage the use of *Clarus* data to other existing or planned state ITS systems. The private sector personnel capabilities required parallel those identified above with the addition of personnel knowledgable in ESS data management, quality checking, and data processing. Further, as the efforts will involve the incorporation of complex weather and surface transportation weather data into a set of products specifically intended to promote more effective use by the state transportation agencies and the public, considerable experience specific to surface transportation weather will be required. These include the processes involved with data assimilation methods, numerical weather prediction, and the concepts and methods associated with pavement condition forecasting.

5.5 – Organizational or Personnel Structures

Organizational changes within each state agency will occur based on the application of use of the *Clarus* data service. This may or may not require dedicated personnel depending upon the application of data to current and expected ITS systems across each state. Maintenance personnel may be required for in-house maintenance of ESS system and management of data servers to the *Clarus* database. Training assistance within district or area offices could be accomplished as an additional duty of the ESS manager within that agency.

5.6 – Operations

Policies and procedures will determine a number of hardware and software requirements with the system. Operational concerns of a business-to-government service operating 24 hours a day and 7 days a week requires manpower necessary to facilitate routine and emergency maintenance as necessary. Query policies will establish access and detail the difference between current and historical data from all data sources. Frequency of updates and queries, manual or automatic, will be described to ensure capable standard with existing and planned ITS infrastructure across each state, weather service providers, road weather service provides, 511 systems and public users of state provide data systems. Network administration will be necessary to protect infrastructure, databases, and middleware systems to ensure availability around the clock.

5.7 – Training

Training should be established at both the *Clarus* level and state level. A "train the trainer" system of operations should be developed to facilitate multiple users across each state access to query the database, report elements, maintain sites, and management shared data. With development of a user guide to *Clarus*, training should be constructed to take no more than a single one-day training class with refresher training required only with major system updates or application enhancements. Training should be presented before regular use of the *Clarus* system begins.

5.8 – Maintenance

Maintenance must be provided within the system across data systems. ESS system will require calibration and maintenance, state ESS servers will be maintained locally, and *Clarus* system servers, middleware systems and programs will require maintenance at the *Clarus* centralized location. In all cases, routine, emergency, and corrective maintenance must be planned and managed at all levels. Upgraded or expanded services providing for the use of the *Clarus* data will require specific additions to the maintenance schedule. Depending upon the location of the equipment, systems or programs, government, maintenance contractor, or development personnel will need to be used for these purposes.

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Section 6. Operational Scenarios

The premise of the *Clarus Initiative* is that the needs of various end-users will be satisfied with the provision of improved road weather services through data available from the *Clarus* System, the services provided through the *Clarus Initiative* efforts of state transportation agencies, and from value-added products created by members of the weather service provider community. Data from *Clarus* combined with other weather and road condition data routinely available to the weather service provider community are transformed into analyses and forecasts of future weather and road weather. These products are an essential part of the decision support tools used by transportation agencies and the general traveler community.

An innovative combination of *Clarus* data with other data/information sources along with creative methods of delivery frames the vision of the North/West Passage for a regional *Clarus* demonstration. The framework of the regional *Clarus* demonstration concept of operation is show in Figure 6. The high-level diagram encapsulates the broader use case scenarios found within the scenarios that include a Regional Road Weather and Road Condition Reporting, Enhanced Road Weather Content for 511 Information Systems, an Interstate Advisory / Control Coordination, and an Automated Alert and Notification Service.

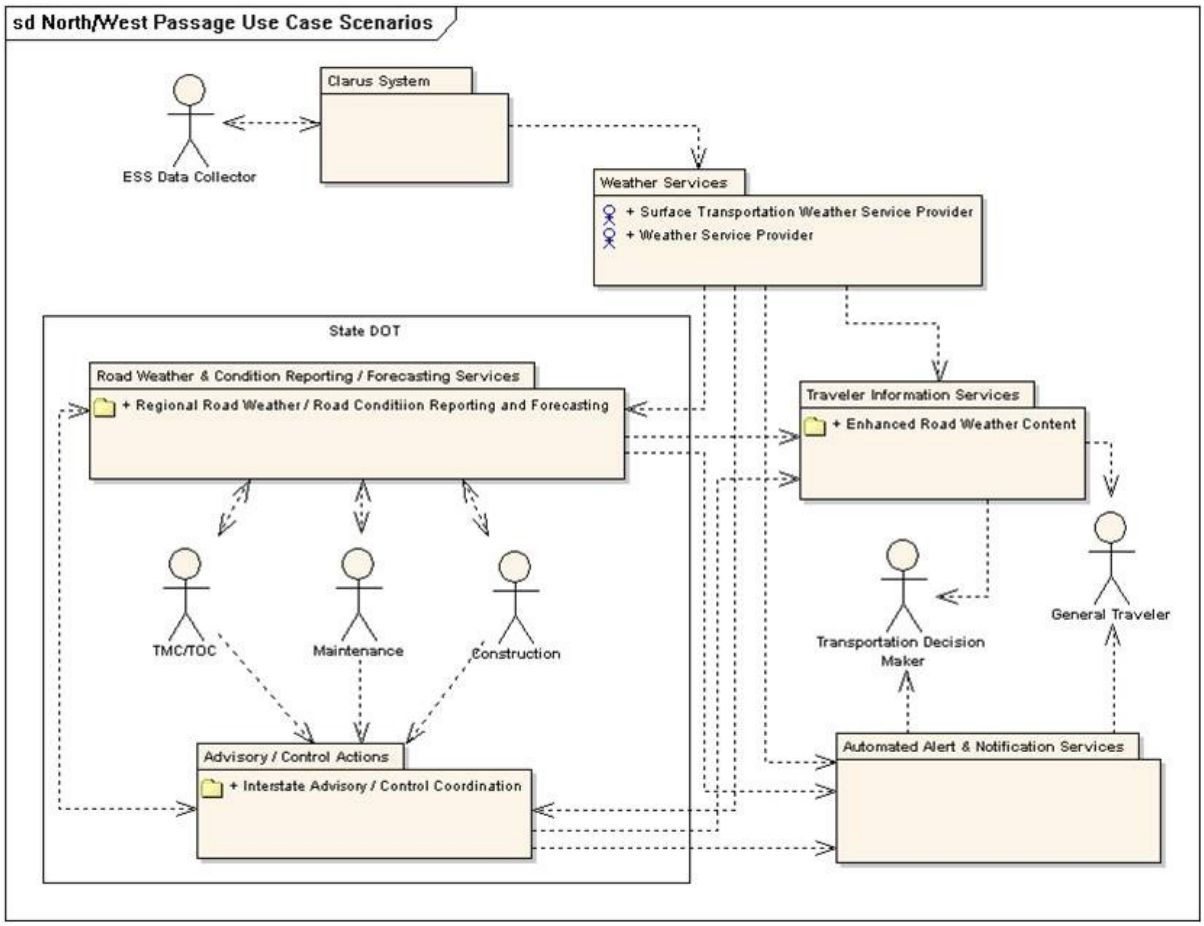

Figure 6. Unified modeling language (UML) framework package diagram of the four North/West Passage Use Case Scenarios defining the regional *Clarus* demonstration concept.

Each of these use case scenarios are presented below. A representative description (that is, a vision story) is provided to suggest an example of how the scenario would possibly exist for an end-user during the regional demonstration. A technical description of the use case scenario follows the representative description. The technical description addresses information flows by identifying: 1) the major inputs initiating the desired functionality, 2) functional relationships between data sources and data users, and 3) the primary outputs of the system. Use case diagrams developed using the Object Management Group Unified Modeling Language (UML) version 2 (10) support the technical description. To simiplify the complexity in viewing the diagrams, the use of UML packages have been incorporated in the use case diagrams. Details of the use case diagrams associated with repetitive features are placed in Appendix C. Within these use case diagrams actors (people, agencies, systems, etc.) who are associated with the actions (use cases) are provided. A description of each actor and use case is provided in Appendix D and Appendix E, respectively. The timing of events associated with each use case scenario is provided in a sequence diagram. Following each sequence diagram is a bulleted description of a more generalized combination of entities and actions in the order of occurrence associated with each scenario.

Scenario A – Interstate Advisory and Control Strategy Coordination

Representative Scenario Description

Sam and Sarah Smith had just spent the last eight hours inside the gymnasium at the Tri-State Wrestling tournament where their son, Tony, had participated. The weather was beautiful when they entered the gymnasium earlier that Saturday morning. However, as they stepped out, storm clouds had already begun to gather in advance of a major winter storm moving northeastward from eastern Colorado. They knew it was going to be a long trip from Alexandria (MN) back to Pierre (SD). As they stopped to fill up with gasoline and get a quick late afternoon meal, there was a National Weather Service special weather announcement on the diner's television noting that a winter storm watch had just been issued from Nebraska northward through much of South Dakota. Concerned about the possible difficulties returning home, the discussion over their meal was nervous and full of questions as to the best route home.

The 5:00 p.m. shift change at the South Dakota Statewide Traffic Operations Center (TOC) had just finished and Walter Jones was deep in thought as he scanned the large wall displays providing situational information on the unfolding winter storm now moving into central and eastern South Dakota. Already snow was falling at several inches per hour making for limited visibility and difficult driving conditions in many parts of the eastern third of the state, and the road weather forecast for the remainder of the evening was depicting considerable heavy snow continuing mainly through the northeastern portion of the state. Reports were already coming in from law enforcement officials in Day and Roberts Counties that I-29 was nearly impassable and no travel was advised. Elsewhere across the state, roads were in good to moderate winter driving condition, but Walter's concern was just how long it would be before more routes would become impassable, resulting in the need for road closures. After a short briefing with the rest of the TOC staff, Walter began his hourly update of the North/West Passage Interstate Advisory and Control Coordination database to inform adjacent states of the active advisory and control road weather management strategies across the state.

As the Smith family pulled back onto I-94 heading west from Alexandria towards Fargo (ND), light snow was beginning to fall and their travel plan apprehensions continued to grow. Normally, they would follow I-94 to Fargo, then turn south on I-29 towards South Dakota. It was nearing 7:30 p.m. as they approached within 30 minutes of Fargo and they knew they must make a decision soon. Meanwhile, Walter Jones had just updated the Interstate Advisory and Control Coordination database with the latest information that I-29 northbound from Watertown in northeastern South Dakota had been closed due to

heavy snow. Susan Wieble, shift manager at the North Dakota Statewide Traffic Operations Center, acknowledged the notice of the new controls placed on I-29 by South Dakota Department of Transportation almost instantly. Susan knew immediately that the procedure was to notify the North Dakota DOT Maintenance Office in Fargo and to post the information on the Dynamic Message Signs along I-94 and I-29 that travel southbound into South Dakota was not possible due to heavy snow. Thus, when the Smiths reached Fargo and noticed that southbound on I-29 into South Dakota was closed, they knew they had to alter their travel plans. With the late hour and the long distance yet to go, they collectively decided to stop in Fargo for the evening and continue their journey when the weather improved.

Technical Description

During stakeholder meetings, situations cited by state department of transportation operations personnel described closing a road in a neighboring state that resulted in significant impacts on the transportation actions in their state, such as long lines of vehicles waiting for roads to re-open or travelers needing lodging. Having information in advance or at the time of imposing these controls would provide an effective means of informing the public of travel delays or a need for detours, as well as improve the maintenance coordination across state borders.

The use of advisory and control road weather management strategies is a routine process for state DOTs when road conditions deteriorate during hazardous winter weather. However, the imposition of advisories and controls often is not well communicated with adjacent states, which can result in travel impacts as traffic stalls in areas that are not well prepared to handle the influx of stranded motorists. The development of a process to communicate in a timely manner the changes in road status would permit officials in adjacent states the opportunity to take proactive mitigation steps to reduce the impact on travelers.

Often, the precursor weather events leading to eventual advisory and/or control actions can be discerned from close monitoring of observed weather conditions in adjacent states. This becomes one of the first steps in raising awareness of potential road condition problems in an adjacent state. This brings to bear the value of *Clarus* System ESS data, as it is a mechanism that will permit individuals in any state the opportunity to monitor pavement and weather conditions in nearby states. The availability becomes one of the first activities in the awareness of road weather management strategies in surrounding states. The extension of the ESS data, through a combination with other weather observations, provides the DOT decision makers with added information on trends in expected road weather conditions and becomes an asset in the decision-making process. Using field observations from reliable field sources, such as state patrol and/or maintenance personnel, adds to the ESS data to provide a picture of current and expected road conditions.

The responsibility for establishing advisories and controls will vary by agency policies and procedures and is not expected to be the same for all North/West Passage states. In some situations, state patrol will have a significant voice in the process and in other situations the responsibility will be assigned to maintenance and/or traffic management staff. However, once an advisory or control action has been performed, it is necessary to transmit this information to a common repository or data warehouse where the information from all states can be stored and made available for posting to appropriate channels of information dissemination to appropriate interested stakeholders, including state agencies, travelers, and traveler-related interests.

A major challenge in the exchange of information will be establishing common protocols and formats for information transmittal and storage. The communications coordinator will have oversight for the

collection of individual state advisory and control information will required to populate the multi-state advisory and control actions database.

The information that follows provides a systematic flow of activities and depicts a general scenario for how an advisory and control coordination and communication system function would occur. Figure 7 provides a Use Case Scenario diagram associating the individuals, agencies, and organizations (actors) that perform the actions (use cases) leading to outputs to the end users (actors). Either dashed lines or solid lines connect actors and use cases. The dashed lines denote a dependency between the two connected features. Solids lines refer to an association between the two connected entities. The lines are not indications of data flow but rather an indication of an action or response to an action. However, often these actions result in an information and/or data exchange.

Details of use cases within packages not described in Figure 7 are found in Appendix C. A listing of all the actors and use cases, including a brief technical description found within the Use Case Scenario diagram, is found in Appendix D and Appendix E. Figure 8 depicts the Use Case Scenario in a time sequence of use cases from the collection of ESS data to the final delivery of end-user products and services. Following this figure is a description of activities and requirements associated with this sequence of use cases. Each successive heading and set of bullets constitutes the next stage of activities with a general flow of time increasing as the list progresses. The entity (actor) responsible for each is noted on the line before each set of bullets.

The Use Case Scenarios provided in this Concept of Operations have a common foundation built upon the system or service packages composed from existing statewide ESS networks, the *Clarus* System, weather analysis and forecasting capabilities from weather service providers and surface transportation weather service providers. These attributes and qualities combined with a systematic approach to efforts by maintenance and traffic management to incorporate weather and road conditions into planning and decision-making provide a basis for supporting each of the Use Case Scenarios offered. This basis is depicted in each primary Use Case Diagram as a collection of UML referenced packages. This affords an opportunity to simplify the Use Case diagrams and to focus on specific functions performed by the action of interest to a scenario. A description of each of the foundation packages is provided in Appendix C.

The availability of ESS data from Clarus, combined with additional external weather data, is provided to actors within the State DOT package to support the incorporation of road weather elements into the determination of advisory and control road weather management strategies across the North/West Passage states. The objective of this scenario is realized as the state from each state is aggregated to provide an interstate portal and/or database for providing cross-jurisdictional advisory and/or control information to travelers. Feedback actions result from the interstate advisory/control information through a notification of condition back to the weather services and the state DOT entities.

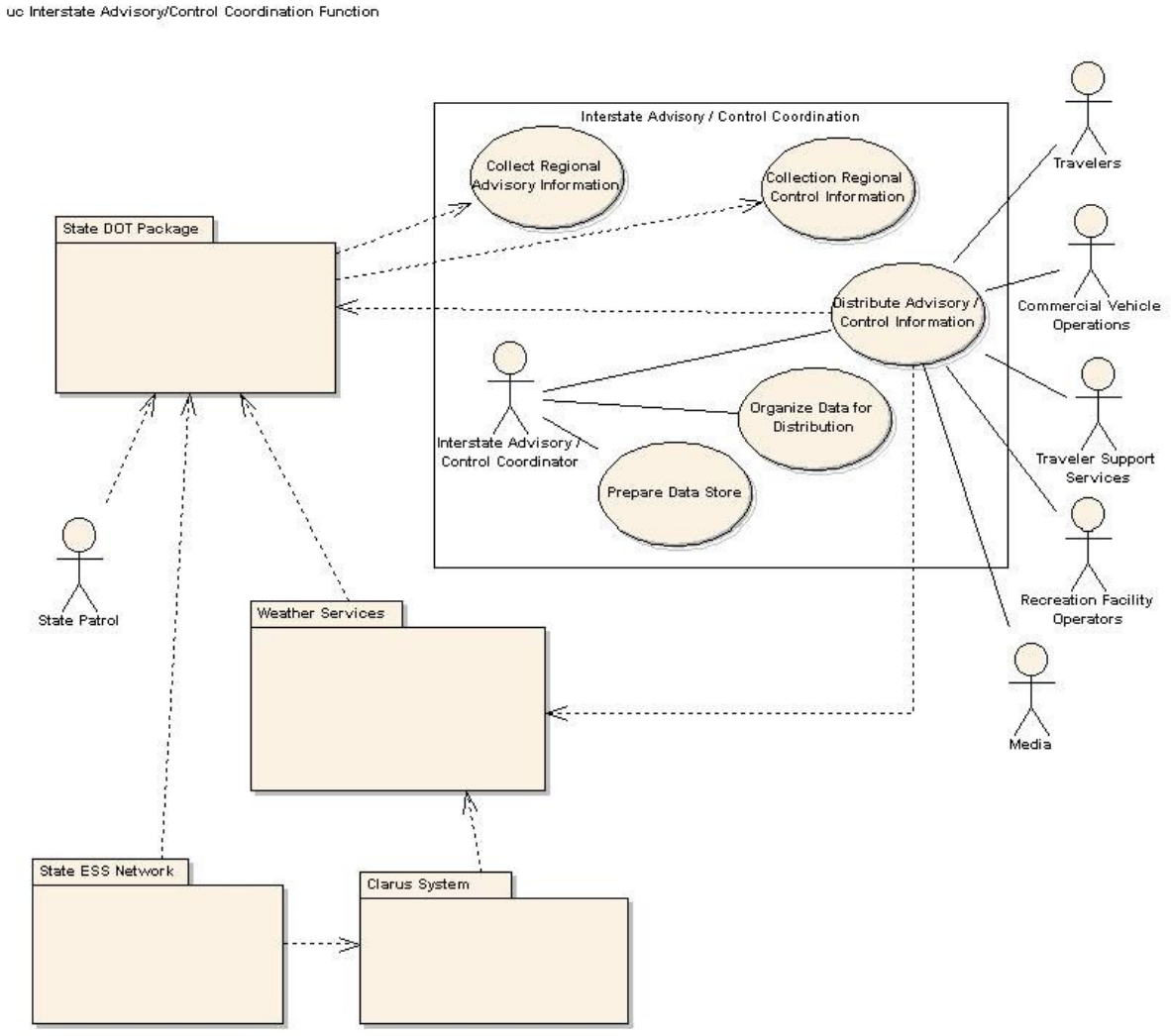

Figure 7. Use Case Diagram based upon the functionality defined for the Interstate Advisory/Control Coordination Function.

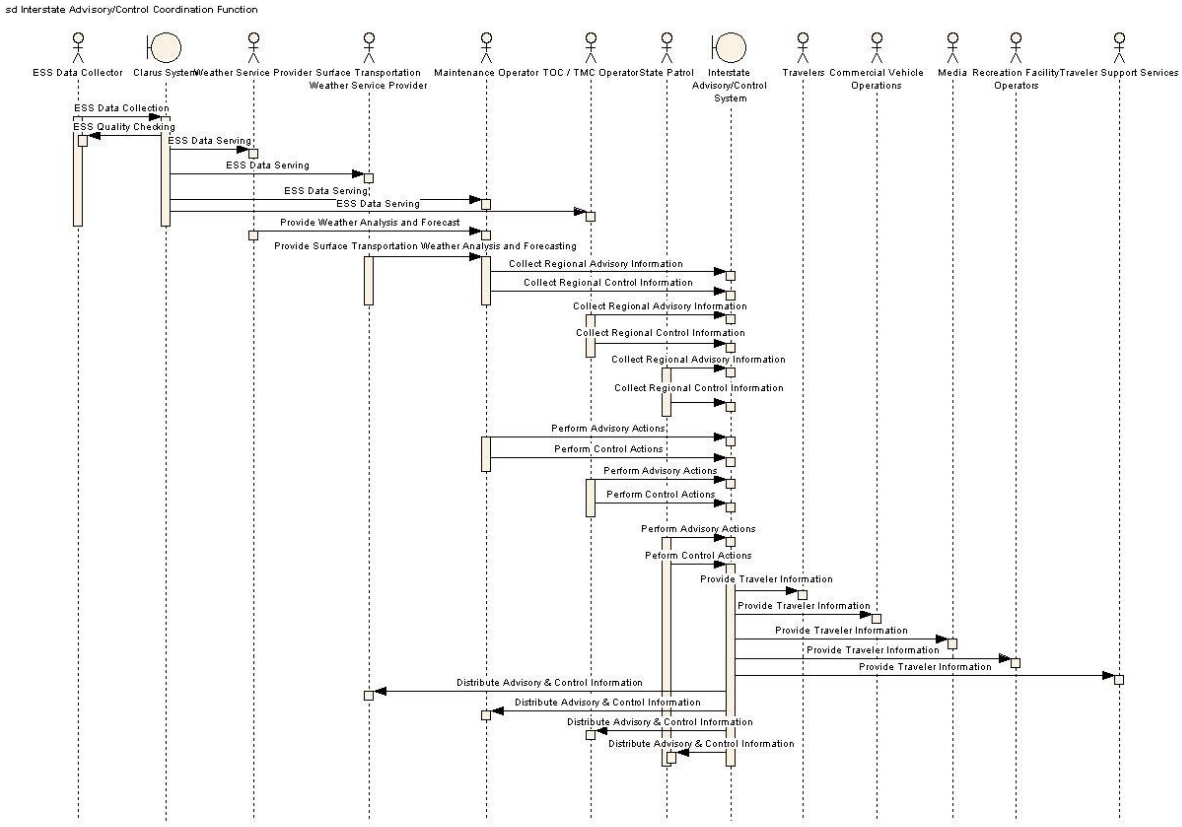

Figure 8. Sequence diagram for the Integrated Advisory / Control Coordination Function

ESS MEASUREMENT – TRANSPORTATION AGENCY

- Weather and pavement values measured in field Environmental Sensor Station (ESS)
- Weather and pavement values stored in field ESS as current report
- Aggregated weather and pavement values stored in field ESS as a series of reports

ESS COLLECTION – TRANSPORTATION AGENCY

- ESS Data Collector polls ESSs and transfers new stored reports in stored series from each ESS
- ESS Data Collector stores reports in database

ESS CONSOLIDATION - CLARUS

- *Clarus* server directly collects data from the ESS Data Collector and Vehicle Data Collector
- Collection process performs quality control checks on incoming data and flags obvious errors
- *Clarus* server stores the data with quality control flags
- *Clarus* server accepts and stores External Weather data for quality assurance check
- Data from multiple sites is sorted into data sets having common date and time and location reference

ESS QUALITY ASSURANCE CHECK - CLARUS

- External Weather data is compared with *Clarus* data for the purpose of data validation and quality assurance processing
- Quality assurance check is run on the time and location sorted data
- Observations deviating from expected value by a specified amount are flagged as potential errors
- *Clarus* stores the error flags with the data
- *Clarus* sends notification to the data provider when suspect data occur

ESS DATA TRANSFER - CLARUS

- Data in the *Clarus* database are acquired by public and private members of the Service Provider community based on timeframe and location

DATA INTEGRATION – SERVICE PROVIDER

- The Service Providers collect, store, and consolidate the *Clarus* data with observed meteorological data from various other sources
- The Service Providers acquire forecast guidance products to complement the observed data
- Observed data are consolidated and composed into presentations showing the data from various sites displayed on a GIS background
- The observed and forecasted data are composed into weather forecast products
- The forecasts are organized into text and graphical presentations

DATA TRANSFORMATION – SERVICE PROVIDER (WEATHER AND SURFACE TRANSPORTATION WEATHER)

- Meteorological data are run through a pavement condition model that transforms the weather forecast components into projection of pavement temperatures and road conditions
- Pavement conditions are computed for segments of a given highway having relatively uniform physical and environmental characteristics
- Computed pavement temperatures and road conditions are organized into tabular and graphical representations of current and forecasted pavement conditions

ADVISORY GENERATION – STATE AGENCY (TRAFFIC MANAGER, STATE PATROL, MAINTENANCE OPERATOR)

- Assess service provider weather forecast data to determine extent and persistence of current road weather conditions
- Updates road condition reports to provide latest available status of pavement conditions
- Monitors current road conditions and trends in forecast road conditions to develop awareness of potential need for road advisory generation
- Generates appropriate advisory messages as needed following standard practices

CONTROL GENERATION - STATE AGENCY (TRAFFIC MANAGER, STATE PATROL, MAINTENANCE OPERATOR)

- Assess service provider weather forecast data to determine extent and persistence of current road weather conditions
- Evaluates the safety and mobility impacts and determines where lower thresholds may be reached
- Updates road condition reports to provide latest available status of pavement conditions
- Monitors current road conditions and trends in forecast road conditions to develop awareness of potential need for road control generation
- Generates appropriate control actions, messages, and dissemination as needed following standard practices

ADVISORY / STRATEGY COORDINATION – STATE AGENCY or SERVICE PROVIDER

- Assimilate advisory action messages from participating state agencies
- Assimilate control action messages from participating state agencies
- Index messages within a web portal or database for ease of retrieval
- Maintain coordination with all states to maintain timeliness and reliability of submitted data

ADVISORY / STRATEGY COMMUNICATION – STATE AGENCY or SERVICE PROVIDER

- Facilitate access to advisory / control database
- Maintain communications protocols and network accessibility to data
- Service external queries and provide user support assistance as needed
- Provide routine communications with state entities to maintain operational lines of communications

TRAVEL INFORMATON – STATE AGENCY or SERVICE PROVIDER

- Access latest advisory / control information
- Fuse interstate advisory / control information with routine traveler information message content
- Deliver traveler information message via computer telephony and/or web delivery methods

Scenario B – Enhanced Weather Content for 511 Information Systems Function

Representative Scenario Description

Two days after Christmas, Michael Roberts, a 39-year-old resident of Madison, Wisconsin gets ready to set upon a new life adventure. After three years of law school, he has accepted what he believes to be his dream job in Seattle, Washington with a national law firm. Accepting the position, he agreed to be in place and ready to begin work by January 10th. With his pregnant wife, two children, two vehicles and one trailer, Michael embarks upon his most important trip, a new life for his family 1927 miles across the country, in the middle of the winter across the Great Northern Plains and Rocky Mountains.

Michael, a former Air Force fighter pilot, understands the importance of flight planning and approached his trip with the same search for intelligence on the best travel route. In planning the trip, Michael remembered a debate in law school. The issue was liability of state government and among the many issues that surfaced was one referencing a telephone traveler information system known as 511. The discussions focused on the detail and reliability of information for the traveler, particularly if the state sources were the best available. He recalled that the class investigation of the system highlighted actual current road and weather conditions from sensors across the region.

This sensor information, verified and quality-checked for use from a system known as *Clarus*, was then incorporated in current condition reports as well as integrated into high resolution weather and road condition models. These models were then analyzed by trained meteorologists to produce a highway travel-planning tool with a level of dependability that had never been seen or experienced before. Michael remembered that this information was included in what had become known as an "All Hazards" report for all state routes within a number of states. These "All Hazards" reports integrate this quality-checked information of current conditions, forecasted conditions, accidents, closures, construction, and any number of events that are key to travel planning. With this knowledge, Michael plans his route and prepares a secondary route as a backup plan.

Michael and Lori, with their children, Ken (8) and Julie (4), pack the cars and trailer at 8 o'clock Tuesday morning, and focus on their plan. The plan called for specific checks of highway conditions along the route and alternate choices should conditions become restrictive across the primary route. Michael calls 511 to determine the current and forecasted conditions at the first two key points along the first leg of the trip: the I-90/I-94 junction in Wisconsin, forecasted weather and road conditions for I-90 across South Dakota, and I-94 across North Dakota. With a storm moving out of Colorado into Nebraska and South Dakota that could close highway systems, Michael and Lori decide to take I-94 across North Dakota with the goal of making it to Fargo, ND about the time the storm is moving across I-94 in Minnesota. The next morning, the plan calls for checking I-94 and US Highway 2 across North Dakota and Montana. A storm front moving across the southern border of North Dakota and Montana closed I-94 along the state line, leaving the couple with concerns on when the questionable road conditions along I-94 will be cleared. Choosing their alternate route, Michael and Lori decide to drive north to US Highway 2 to enter Montana and continue west.

By Friday morning, Michael and Lori prepare to leave Havre, Montana, checking US 89 to I-15 and I-90 into Idaho. The planned routes now provide for I-15 to I-90 across Idaho, or continue on US Highway 2 to I-90 into Washington. With clear road conditions reported across both routes, Michael and Lori decided to take the southern route on US 89 to I-15 and I-90 to avoid US Highway 2 through the mountains with a trailer, arriving in Spokane, Washington Friday night. Their trip is almost complete,

with only one more day until their new life begins. Starting their trip on Saturday morning, the only remaining points of interest along the route include mountain pass conditions across the State of Washington and if they will have stop along the way. Both current and forecasted conditions are clear and the future is in sight…

Technical Description

Present 511 systems have limited capabilities to access information across borders and are limited to the exchange of information with adjacent states. Enhancing available weather information and providing mechanisms to permit the data warehousing of traveler information, including current /forecast road conditions and weather conditions would provide a framework enhancing traveler decision support along full highway corridors spanning multiple states.

To enable 511 to become a ubiquitous source for traveler information the barriers to information should not be at state borders. This function has a focus to provide accessibility to 511 content beyond a caller's present state location and even beyond that of an adjacent state. Long-distance travelers can be faced with route planning challenges during inclement weather where a decision to proceed can be based upon knowing not the present road and weather conditions but those anticipated at the time of arrival. The challenges in supporting this longer-range information capability go beyond physical challenges of predicting the future. They include overcoming 511 system data / information standardization and communications protocols. Presently, systems are largely limited to accessibility to information for their present state in which they are calling. If the 511 system has the capability of spanning across a state border, it is often due to the same 511 service provider supporting both states. North/West Passage has made some initial strides in overcoming this barrier through development efforts to link the 511 system in Minnesota to that found in North Dakota and South Dakota. However, in no present system does there exist a capability to extend 511 service coverage along an entire Interstate or US Highway reaching beyond two states. As such, this 'reach' limitation places restrictions on a more optimal usage of 511 for long distance travel planning.

In this function, the vision is to provide a mechanism to facilitate the accessibility of 511 information for any Interstate or US Highway across the eight-state North/West Passage Pooled Fund Transportation Study. The essence of the activity is to pool information resources in use by each state for access by each state's 511 service provider for delivery over the width of the corridor.

As weather and road conditions form the basis for 511 services in the North/West Passage states, the use case follows the premise that quality road weather and road condition information is a priority that will be enhanced by the greater accessibility to all ESS observations within the North/West Passage domain. Hence, the early aspects of the use case scenario has a functionality that is consistent with that found within present and pending 511 services for the eight North/West Passage states.

The information that follows provides a systematic flow of activities and depicts a general scenario for how a service providing enhanced road weather content for 511 information systems function would occur. Figure 9 provides a Use Case Scenario diagram associating the individuals, agencies, and organizations (actors) performing the actions (use cases) leading to outputs to the end users (actors). A listing of all the actors and use cases including a brief technical description found within the Use Case Scenario diagram follows Figure 9. Figure 10 depicts the Use Case Scenario in a time sequence of use cases from the collection of ESS data to the final delivery of end-user products and services. Following this figure is a description of activities and requirements associated with this sequence of use cases. Each successive heading and set of bullets constitutes the next stage of activities with a general flow of time

increasing as the list progresses. The entity (actor) responsible for each is noted on the line before each set of bullets.

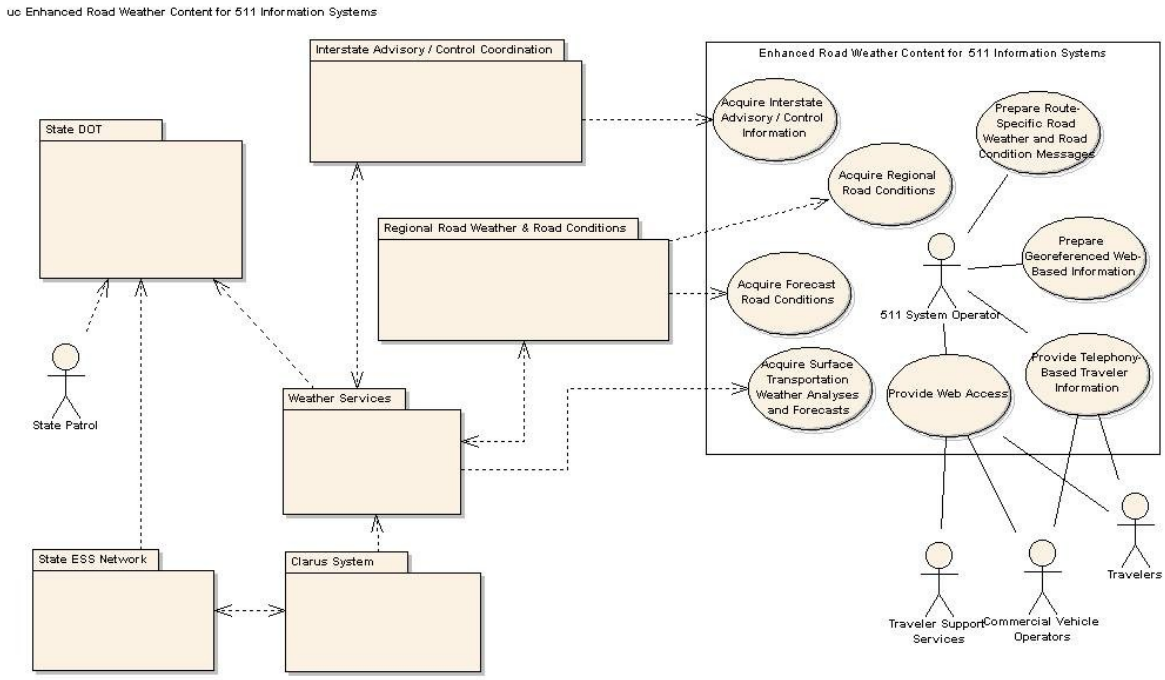

Figure 9. The Use Case Diagram based upon the functionality defined for the Enhanced Road Weather Content for 511 Information Systems Function.

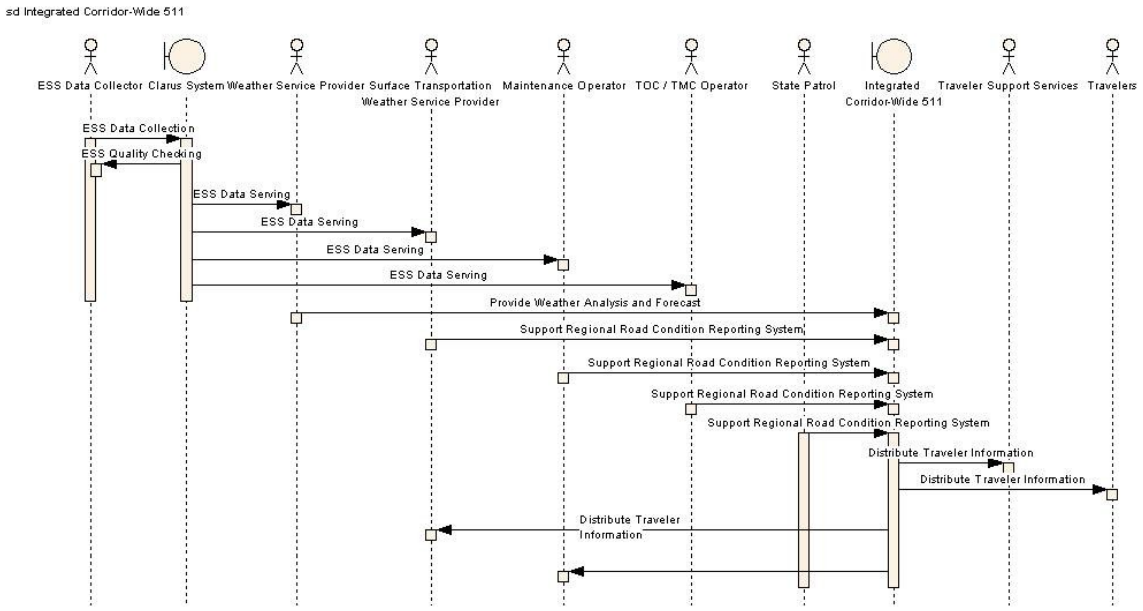

Figure 10. Sequence diagram for the Enhanced Road Weather Content for 511 Information Systems Function

ESS MEASUREMENT – TRANSPORTATION AGENCY

- Weather and pavement values measured in field Environmental Sensor Station (ESS)
- Weather and pavement values stored in field ESS as current report
- Aggregated weather and pavement values stored in field ESS as a series of reports

ESS COLLECTION – TRANSPORTATION AGENCY

- ESS Data Collector polls ESSs and transfers new stored reports in stored series from each ESS
- ESS Data Collector stores reports in database

CONSOLIDATION - CLARUS

- *Clarus* server directly collects data from the ESS Data Collector and Vehicle Data Collector
- Collection process performs quality control checks on incoming data and flags obvious errors
- *Clarus* server stores the data with quality control flags
- *Clarus* server accepts and stores External Weather data for quality assurance check
- Data from multiple sites is sorted into data sets having common date and time and location reference

QUALITY ASSURANCE CHECK - CLARUS

- External Weather data is compared with *Clarus* data for the purpose of data validation and quality assurance processing
- Quality assurance check is run on the time and location sorted data
- Observations deviating from expected value by a specified amount are flagged as potential errors
- *Clarus* stores the error flags with the data
- *Clarus* sends notification to the data provider when suspect data occur

DATA TRANSFER - CLARUS

- Data in the *Clarus* database are acquired by public and private members of the Service Provider community based on timeframe and location

DATA INTEGRATION – SERVICE PROVIDER

- The Service Providers collect, store, and consolidate the *Clarus* data with observed meteorological data from various other sources
- The Service Providers acquire forecast guidance products to complement the observed data
- Observed data are consolidated and composed into presentations showing the data from various sites displayed on a GIS background
- The observed and forecasted data are composed into weather forecast products
- The forecasts are organized into text and graphical presentations

DATA TRANSFORMATION – SERVICE PROVIDER (WEATHER AND SURFACE TRANSPORTATION WEATHER)

- Meteorological data are run through a pavement condition model that transforms the weather forecast components into projection of pavement temperatures and road conditions
- Pavement conditions are computed for segments of a given highway having relatively uniform physical and environmental characteristics
- Computed pavement temperatures and road conditions are organized into tabular and graphical representations of current and forecasted pavement conditions

511 SERVICE PREPARER – STATE AGENCY or SERVICE PROVIDER

- Acquires surface transportation weather service provider forecast for route-specific locations within the state for which the service is being provided
- Updates road condition reports to provide latest available status of pavement conditions
- Updates incident and construction information found within the road condition reporting system to provide the latest available status in 511 message
- Transforms the content of available information into content specific to the information delivery format or the 511 system being used
- At a designated schedule the state's 511 content is posted to the multi-state integrated 511 database

NORTH/WEST PASSAGE 511 SYSTEMS – STATE AGENCY or SERVICE PROVIDER

- Manages data acquisition from each North/West Passage state
- Transforms each state's 511 data into common format for database insertion
- Indexing of database to provide access by each state's 511 service provider
- Provides system management and administration to 511 database
- Maintains open dialog and communications with each state participants 511 coordinator

TRAVEL INFORMATON PROVIDER – STATE AGENCY or SERVICE PROVIDER

- Access 511 database to retrieve required data to satisfy end-user query
- Fuse out-of-state 511 information, where requested by the end user, with traveler information message content from the in-state 511 system

Scenario C – Regional Road Weather and Road Condition Reporting System

Representative Scenario Description

In October 2009, Lt. Robert Fischer of the Montana State Highway Patrol was traveling in northwestern Montana along Interstate 90 westbound towards the Idaho state line with a new member of the division, Patrolman John Wilson. Standard department procedures required a newly assigned patrolman to ride with a veteran during the first six months of evaluation.

Along the way, Robert explains certain duties and responsibilities that they handle in the field that may or may not be specifically taught at the academy. An hour into the shift, the team was advised that Idaho closed I-90 at the border to prevent traffic from entering the state because a blizzard was reducing visibilities down to zero in some places. John asked, "How is that going to affect our shift? Will we head towards the state line now to monitor conditions as vehicles start to backup into the state?" Robert calmly stated, "Well, if this was two years ago, you would be right. Idaho closing I-90 would create a backup of traffic along this interstate to the point where you would think you're in a mall parking lot. Without a way to share the information and provide advanced warnings, cars and trucks would just keep traveling until they reach the closure point. Holding trucks at the state line and ensuring everyone has water and food when the hotels and motels are full would become our primary responsibility."

Robert then explained that in 2007 several Departments of Transportation began a research program known as *Clarus*. One of the many focuses of the program was to integrate road and weather data across state lines. After the states worked together to integrate multi-state road reporting systems, people traveling in Montana, not to mention North Dakota or Minnesota traffic, can now be informed that the boarder of Idaho and Montana is closed. This information can allow traffic to choose an alternate route or change their travel plans and destinations long before they reach the state line and get stuck with no place to rest.

"Remember that Dynamic Message Sign you saw earlier?" Robert asks. "By now, that sign is warning travelers of the road closure ahead so they can adjust their travel plans. This program established a multi-state road condition reporting system that allows states within a given region to communicate road conditions and status to each other. This information is then shared with a number of traveler information systems, hotels, gas stations, and official services along the route to facilitate services and travel planning. If someone calls 511, sees a Dynamic Message Sign en-route, or visits a road reporting website before starting their trip, the information is provided directly to them so they can change or adjust their plans."

"The big advantage to us has been that instead of taking on a "babysitting" role during these events, we are now available to continue to do our jobs of serving and protecting the public," explains Robert. "Now, if someone gets stranded in a storm, we can go assist in that situation instead of being tied up monitoring border conditions." John then asks, "Well then, since the weather and road conditions have no effect on our patrol, where are we headed to tonight?"

Technical Description

Under the current Federal transportation act (SAFETEA-LU, Section 1201), the ITS Architecture and Standards Rule/Policy requires state and local governments to address information needs and data exchange associated with highway information and monitoring. Many of the North/West Passage states have addressed this in ITS architectures to provide an integrated (statewide) road condition reporting

system. However, the utility of the information within a statewide road condition reporting system frequently extends beyond the boundaries of a given state and serves as a useful planning and decision-making tool for users from winter maintenance personnel to travelers.

Considering the current efforts toward statewide road condition reporting systems in the North/West Passage sates, the technical areas associated with this function involve the collection of content from the participating state agencies, maintaining the content in a relational database that incorporates the varying content among the states, and providing distribution methods for user access of the database. The data collection efforts are largely establishing the communications protocols and access methods to state agency road condition reporting system databases. The extraction of content from the state information flows can be addressed by adhering to ITS data standards when aggregating data from differing road condition reporting systems. Establishing an appropriate database schema incorporating the desired system content would initially be a composite of present fields within the state databases. However, the addition of predictive fields for pavement and driving conditions will require new categories of information within the regional database where the majority of this information will require the coordination with the surface transportation weather service provider.

The distribution of information will involve database query methods that will be either client-side applications or web-based queries. The client-side applications will be lightweight applications that are platform independent providing the capability of data viewing and input. The input capabilities will be limited by authorization privileges granted to the end-user. The client-side applications may also be configured to provide a large access "sweep" of the database to permit value-added providers access to information for incorporation into further product application requiring the road condition reporting system information. An example of this latter application would be the incorporation of the current regional road condition reporting system information into the Pooled Fund Study Maintenance Decision Support System, which would then use the information to define the current state of the regional road network for pavement condition forecasting and to display the information for maintenance personnel.

The web-based access of the regional road condition reporting system would support a broader, less technical stakeholder base of users. This web access would either be provided as a new web portal for regional road condition information or provided by an individual state agency using their existing web support for traveler information.

The information that follows provides a systematic flow of activities and depicts a general scenario for how a regional road condition system function would occur. Figure 11 provides a Use Case Scenario diagram associating the individuals, agencies, and organizations (actors) that perform the actions (use cases) leading to outputs to the end users (actors). A listing of all the actors and use cases including a brief technical description found within the Use Case Scenario diagram follows **Error! Reference source not found.**. **Error! Reference source not found.** depicts the Use Case Scenario in a time sequence of use cases from the collection of ESS data to the final delivery of end-user products and services. Following this figure is a description of activities and requirements associated with this sequence of use cases. Each successive heading and set of bullets constitutes the next stage of activities with a general flow of time increasing as the list progresses. The entity (actor) responsible for each is noted on the line before each set of bullets.

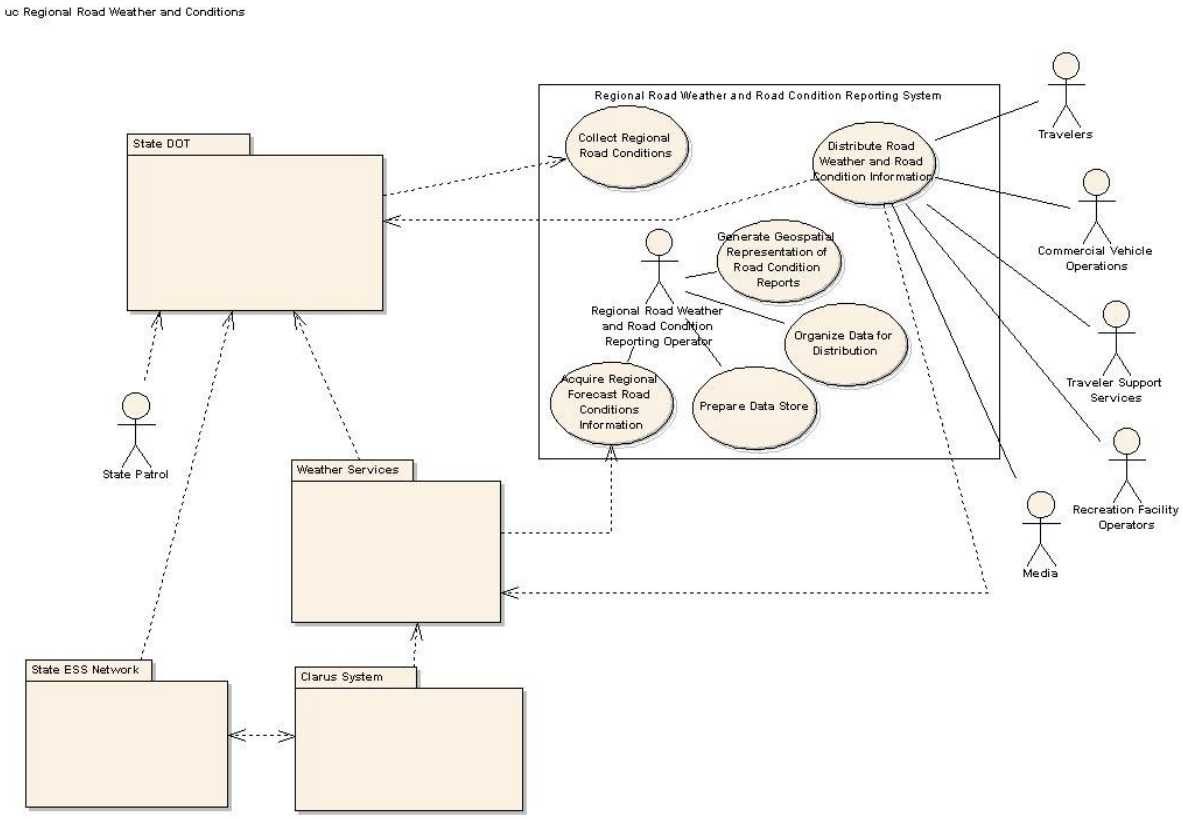

Figure 11. Use Case Diagram based upon the functionality defined for the Regional Road Weather and Road Condition Reporting System

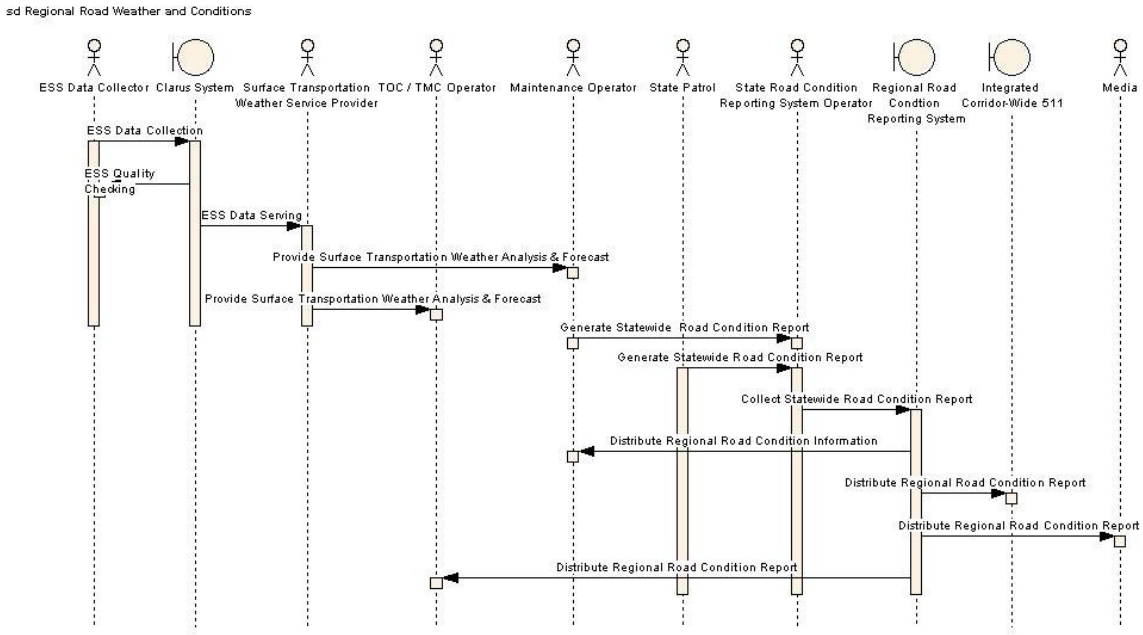

Figure 12. Sequence diagram for the Regional Road Weather and Road Condition Reporting Function

ESS MEASUREMENT – TRANSPORTATION AGENCY

- Weather and pavement values measured in field Environmental Sensor Station (ESS)
- Weather and pavement values stored in field ESS as current report
- Aggregated weather and pavement values stored in field ESS as a series of reports

ESS COLLECTION – TRANSPORTATION AGENCY

- ESS Data Collector polls ESSs and transfers new stored reports in stored series from each ESS
- ESS Data Collector stores reports in database

CONSOLIDATION - CLARUS

- *Clarus* server directly collects data from the ESS Data Collector and Vehicle Data Collector
- Collection process performs quality control checks on incoming data and flags obvious errors
- *Clarus* server stores the data with quality control flags
- *Clarus* server accepts and stores External Weather data for quality assurance check
- Data from multiple sites is sorted into data sets having common date and time and location reference

QUALITY ASSURANCE CHECK - CLARUS

- External Weather data is compared with *Clarus* data for the purpose of data validation and quality assurance processing
- Quality assurance check is run on the time and location sorted data
- Observations deviating from expected value by a specified amount are flagged as potential errors
- *Clarus* stores the error flags with the data
- *Clarus* sends notification to the data provider when suspect data occur

DATA TRANSFER - CLARUS

- Data in the *Clarus* database are acquired by public and private members of the Service Provider community based on timeframe and location

DATA INTEGRATION – SERVICE PROVIDER

- The Service Providers collect, store, and consolidate the *Clarus* data with observed meteorological data from various other sources
- The Service Providers acquire forecast guidance products to complement the observed data
- Observed data are consolidated and composed into presentations showing the data from various sites displayed on a GIS background
- The observed and forecasted data are composed into weather forecast products
- The forecasts are organized into text and graphical presentations

DATA TRANSFORMATION – SERVICE PROVIDER (WEATHER AND SURFACE TRANSPORTATION WEATHER)

- Meteorological data are run through a pavement condition model that transforms the weather forecast components into projection of pavement temperatures and road conditions
- Pavement conditions are computed for segments of a given highway having relatively uniform physical and environmental characteristics
- Computed pavement temperatures and road conditions are organized into tabular and graphical representations of current and forecasted pavement conditions

PROVIDE ROAD CONDITIONS – STATE AGENCY (TRAFFIC MANAGER, STATE PATROL, MAINTENANCE OPERATOR)

- Assess service provider weather forecast data to determine extent and persistence of current road weather conditions
- Updates road condition reports to provide latest available status of pavement conditions
- Monitors current road conditions and trends in forecast road conditions to develop awareness of potential need for road advisory generation
- Generates appropriate advisory messages as needed following standard practices

REGIONAL ROAD CONDITIONS - STATE AGENCY or SERVICE PROVIDER

- Collect and store assorted statewide road conditions from participating regional states
- Collect and store assorted statewide route-specific road weather conditions and forecast conditions
- Monitors road condition database for quality and consistency in information
- Generates geospatial representation of road condition information using acceptable geospatial database and display standards
- Provide query methods to mine use required and requested road condition data
- Support database transactions with the regional 511 information system
- Provide road condition information back to statewide road condition systems as requested and/or required to support participating state needs

REGIONAL ROAD CONDTION DISTRIBUTION – STATE AGENCY or SERVICE PROVIDER

- Provide web-based information dissemination methods for data query transactions
- Maintain coordination with all states to maintain timeliness and reliability of submitted data

511 SYSTEM COMMUNICATIONS – STATE AGENCY or SERVICE PROVIDER

- Facilitate access to regional road condition database via 511 communications protocols
- Fuse appropriate road condition information with routine traveler information message content
- Maintain communications protocols and network accessibility to data
- Service external queries and provide user support assistance as needed
- Provide routine communications with state entities to maintain operational lines of communications

BROADCAST ROAD CONDITION INFORMATON – MEDIA

- Access latest regional road condition information
- Provide information on current and projected road conditions to viewers

Scenario D – Automated Alert and Notification System

Representative Scenario Description

Mike, 46, has lived in Minnesota all of his life. He is all too familiar with the winters across the Northern Great Plains. Since 1995, when he began his regional transport company, his winter weather experience has expanded across to the Rocky Mountains. In the early years of his business, he noticed a marked difference between weather reports from the Weather Channel, the National Weather Service, and the local television stations. Many times Mike would turn to his neighbor, Roger, who works for the state Department of Transportation to see what weather information he acquired through state resources.

In 2009, with the growth of his business across six northern plain states, Roger's current weather information was not enough to plan ahead to alter routes for delivery. This fact was discussed between them one morning in Mike's front yard. Roger explained about a new system called *Clarus* that for a small monthly fee, would provide data not only of weather events across the region at specific locations along given routes, but would quality control the information, and provide current and forecasted weather and road conditions derived from this same information. This information would come directly from state owned weather sensors, and would update on a regular basis. If desired, the system could provide pre-selected automated alerts to e-mail, cell phone, or PDA systems as conditions change. He explained to Mike that if he pre-selected his routes, time of day, and criteria of alerts on a webpage, the system would notify him of the selected changes as they occur or forecasted to occur. Roger explained that key decision makers use both in-state and out of state alerts for key sensors and routes to plan and track specific weather events in an effort to maximize their limited manpower and resources with their primary focus on keeping the roads open.

Mike was excited about this opportunity and signed up, programming the company's routine routes and some alternate routes they had been forced to use in the past. A week later, Mike was able to inform two trucks traveling across North Dakota into Montana and Wyoming of a storm front and expected changing conditions across Northern Wyoming (I-90) and Southern Montana (I-90/I-94). With the anticipation of delays, Mike was able to send the Wyoming shipment south on US 85 in South Dakota to reach Wyoming, and the Montana shipment north on US 85 to US 2 to complete the delivery to Havre, MT.

Meanwhile in Montana, the same storm front is affecting travel within the state as well. Jackie, a single mother of two, was preparing to travel with the local basketball team in which her son was the star player, to the state basketball championships in Billings, MT. Jackie had learned of the *Clarus* Automated Alert Notification system through her work at the Montana Department of Transportation in Helena. Knowing how the supervisors across the state received early warnings of events along specific routes coupled with the forecasted weather and road conditions alerts had saved the state over-time and resource costs in planning, she had signed up for the service two days earlier.

With the 12-hour advanced forecasted warning she received for the Billings area and all points between, Jackie advised the team and other parents to get started early and chose an alternate route to head north to Billings. She was relieved that the team and fans arrived about one hour before the storm hit the area. Fortunately, the players for the other team were able to make it to the game, however they were no match for Jackie's son and his team.

Technical Description

The growth in consumer use of information technology and the availability of site-specific road weather information provides an excellent opportunity to merge these capabilities to provide a proactive delivery of site-specific road weather information. The technical requirements to do this are largely contained within the existing infrastructures of the road weather community and those within the telecommunications community. The additional technical requirements to complete the automated alert and notification system function is the fusing of these technologies such that information flows can be established from creation to delivery. The requirements to complete this function will be the construction of a database of information for delivery, a system of communication methods for distribution of information from the database, a set of end-user requirements describing what data is desired along with where and when the information is needed, and a database monitoring and mining capability to apply the end-user requirements that would trigger the extraction, packaging and delivery of the appropriate information.

The database of information will be comprised of regional information found elsewhere in this North/West Passage *Clarus* Regional Demonstration Concept of Operation. Specifically, these data include the regional advisory and control road weather management strategy information, the regional road condition information, and the road weather information contained within the enhanced road weather content 511 traveler information system. A schema describing the structure and content of the database will be required that defines the data available for the alert and notification provision. Query methods will be required that provide access to the database elements that are specified in the end-user alert and notification configuration. Algorithms to identify the geospatial and temporal fields in the database against the end-user's requirements will be needed to select appropriate data that can be checked as to whether a threshold value has been exceeded. With such a threshold exceeded the method or methods of data delivery will need to be evaluated and used to prepare the appropriate packaging of the information to the device or instrument where the user will be receiving the information.

This system is anticipated to be a business-public agency relationship as the nature of the information is across state borders and the method of delivery will be fee-based. It is possible that this endeavor could be supported under a pooled fund program such as the North/West Passage, however the cost recovery mechanisms would need to be identified. No matter the manner of business model chosen for implementation, the function would require access to multi-state information resources as a routine, operational framework and an end-user subscription method need to be developed. This subscription method could be located on state agency and/or private sector provider traveler information web pages for subscription by the traveling public or commercial subscribers. The subscription system within state agencies i.e., winter maintenance, traffic managers, could be located on either a state agency's surface transportation weather web page or a unique web page for the automated alert and notification system, which could be provided either by the state agency or the private sector provider of the service.

The end users of this function are likely to be as much state agencies as travelers. State agency personnel such as winter maintenance professionals would use this system to identify to occurrence or pending occurrence of road weather situations requiring their decision or actions. Travelers, general motorists and commercial vehicle operators, would use this system to alert them to changing driving conditions that might require their alteration in travel actions or plans. The extent into the future the system would provide forecasted conditions would be dependent upon the length of forecast information inherent in other aspects of road weather data generated in other functions (packages) found within this Concept of Operations.

The information that follows provides a systematic flow of activities and depicts a general scenario for how a regional alert and notification system function would occur. Figure 13 provides a Use Case Scenario diagram associating the individuals, agencies, and organizations (actors) that perform the actions (use cases) leading to outputs to the end users (actors). A listing of all the actors and use cases including a brief technical description found within the Use Case Scenario diagram follows **Error! Reference source not found.**. **Error! Reference source not found.** depicts the Use Case Scenario in a time sequence of use cases from the collection of ESS data to the final delivery of end-user products and services. Following this figure is a description of activities and requirements associated with this sequence of use cases. Each successive heading and set of bullets constitutes the next stage of activities with a general flow of time increasing as the list progresses. The entity (actor) responsible for each is noted on the line before each set of bullets.

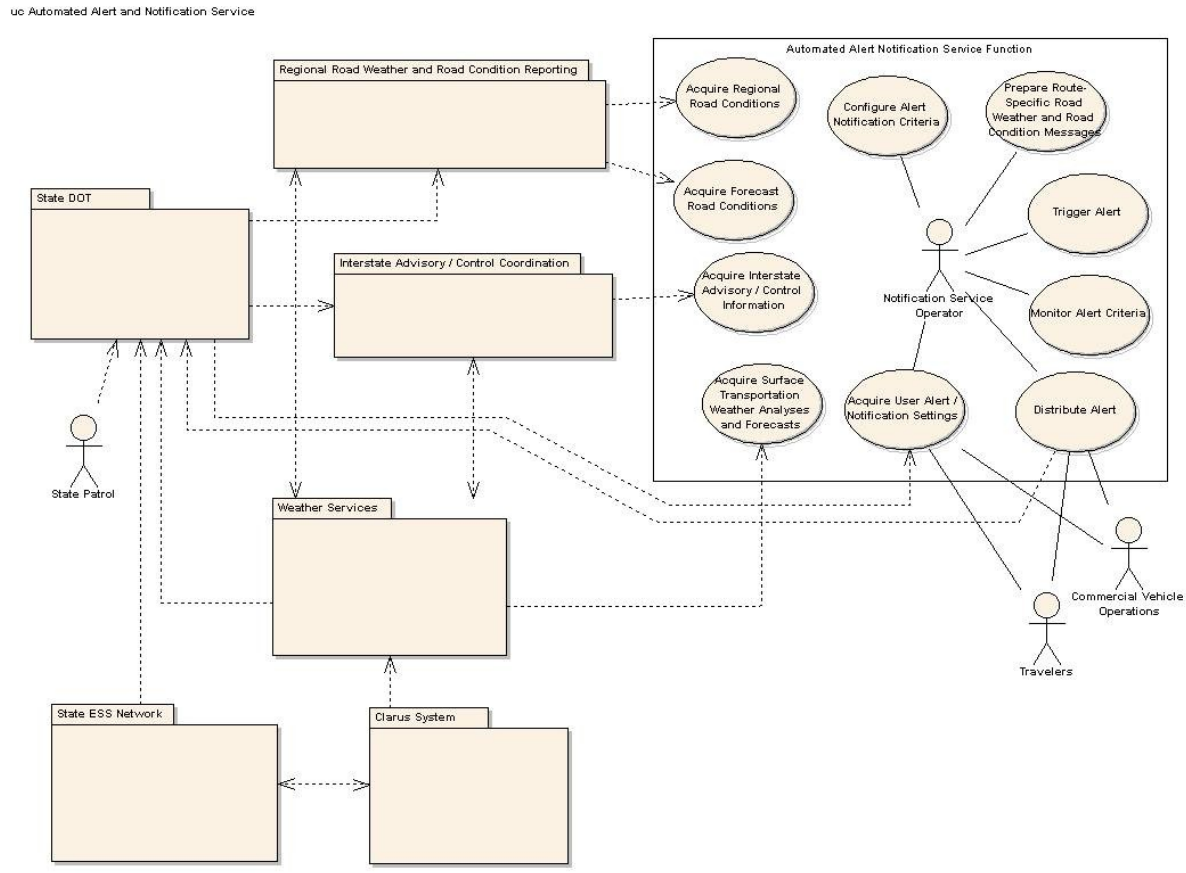

Figure 13. Use Case Diagram based upon the functionality defined for the Automated Alert Notification Service Function

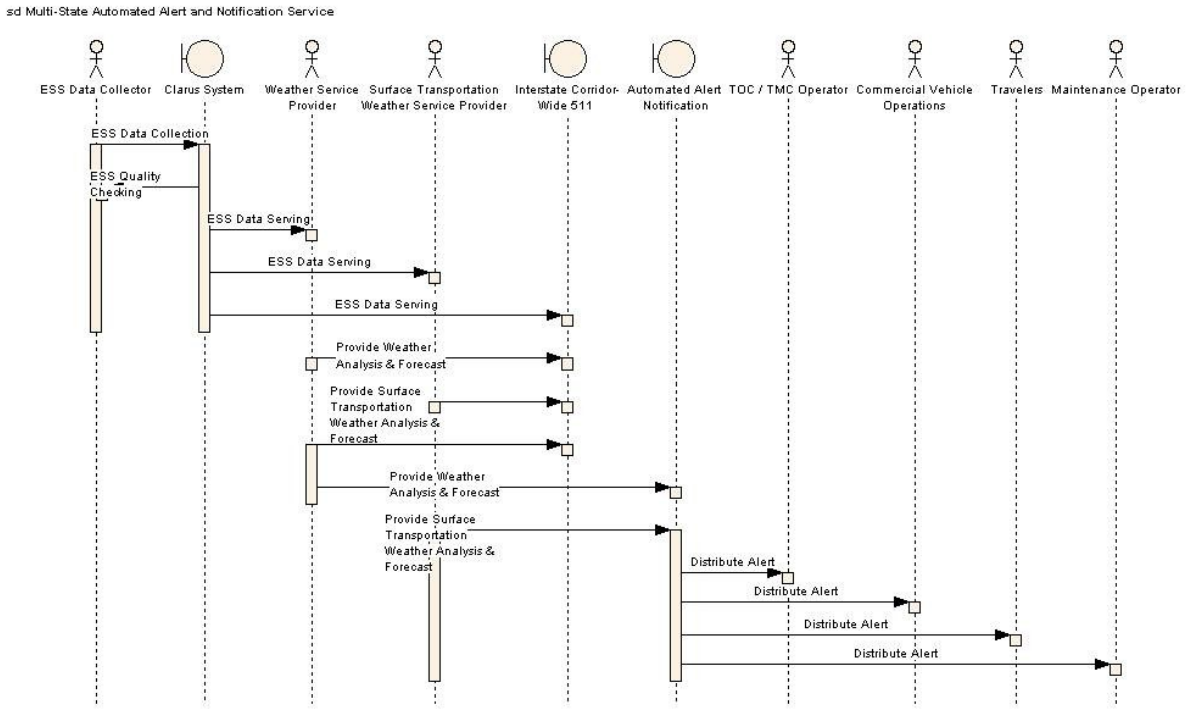

Figure 14. Sequence diagram for the Automated Alert Notification Service Function

ESS MEASUREMENT – TRANSPORTATION AGENCY

- Weather and pavement values measured in field Environmental Sensor Station (ESS)
- Weather and pavement values stored in field ESS as current report
- Aggregated weather and pavement values stored in field ESS as a series of reports

ESS COLLECTION – TRANSPORTATION AGENCY

- ESS Data Collector polls ESSs and transfers new stored reports in stored series from each ESS
- ESS Data Collector stores reports in database

CONSOLIDATION - CLARUS

- *Clarus* server directly collects data from the ESS Data Collector and Vehicle Data Collector
- Collection process performs quality control checks on incoming data and flags obvious errors
- *Clarus* server stores the data with quality control flags
- *Clarus* server accepts and stores External Weather data for quality assurance check
- Data from multiple sites is sorted into data sets having common date and time and location reference

QUALITY ASSURANCE CHECK - CLARUS

- External Weather data is compared with *Clarus* data for the purpose of data validation and quality assurance processing
- Quality assurance check is run on the time and location sorted data

- Observations deviating from expected value by a specified amount are flagged as potential errors
- *Clarus* stores the error flags with the data
- *Clarus* sends notification to the data provider when suspect data occur

DATA TRANSFER - CLARUS

- Data in the *Clarus* database are acquired by public and private members of the Service Provider community based on timeframe and location

DATA INTEGRATION – SERVICE PROVIDER

- The Service Providers collect, store, and consolidate the *Clarus* data with observed meteorological data from various other sources
- The Service Providers acquire forecast guidance products to complement the observed data
- Observed data are consolidated and composed into presentations showing the data from various sites displayed on a GIS background
- The observed and forecasted data are composed into weather forecast products
- The forecasts are organized into text and graphical presentations

DATA TRANSFORMATION – SERVICE PROVIDER (WEATHER AND SURFACE TRANSPORTATION WEATHER)

- Meteorological data are run through a pavement condition model that transforms the weather forecast components into projection of pavement temperatures and road conditions
- Pavement conditions are computed for segments of a given highway having relatively uniform physical and environmental characteristics
- Computed pavement temperatures and road conditions are organized into tabular and graphical representations of current and forecasted pavement conditions

ALERT GENERATION – STATE AGENCY (NOTIFICATION SERVICE OPERATOR)

- Assess service provider weather forecast data to determine extent and persistence of current road weather conditions
- Updates road condition reports to provide latest available status of pavement conditions
- Monitors current road conditions and trends in forecast road conditions to develop awareness of potential need for road advisory generation
- Generates appropriate alert messages as needed following user-defined alert configurations
- Distributes alert notifications using pre-defined telecommunications methods

ALERT NOTIFICATION RECEPTION – STATE AGENCY

- Pre-defined locations, times and data sources for monitoring by alert notification system
- Provides devices or Internet resources for reception of alert notifications
- Applies alert notification information to relevant decision-making processes

ALERT NOTIFICATION RECEPTION – TRAVELER or COMMERCIAL VEHICLE OPERATOR

- Pre-defined locations, times and data sources for monitoring by alert notification system
- Provides devices or Internet resources for reception of alert notifications

Section 7. Summary of Impacts or Improvements

This section includes an analysis of the benefits, limitations, advantages, and disadvantages of the proposed services, and the impacts on each of the stakeholders. It is presented from the viewpoint of each stakeholder so they can readily understand and validate how the proposed services will influence their operations.

7.1 – Effectiveness Evaluation

7.1.1 Summary of Improvements

With the North/West Passage *Clarus* Regional Demonstration, the following general benefits can be expected:

- Traveler system content and quality of content will be extended to a level that should be superior to any such information provided elsewhere in the Nation.
- The volume of site-specific road weather information available to the weather service provider community, state transportation agencies, and the traveling public will be dramatically expanded.
- The automated alert and notification capabilities of the demonstration will shorten the response time to perform maintenance decisions, alter travel actions, and prepare decision makers for road weather related impacts and will provide both an economic and safety benefit.
- The integrated, easily accessible road and weather information will benefit all users of weather information.
- The service functions within the demonstration will improve the traveling public's safety by enabling access to site-specific road and weather information for the areas in which they live and the routes by which they travel.
- The *Clarus* System quality checking will improve the overall data quality utilized to provide support to users of products provided by surface transportation weather service providers and directly consumed by state agencies and the general public.

The North/West Passage *Clarus* Regional Demonstration, when fully implemented with the services described in this Concept of Operations, offers the following benefits to the individual stakeholder groups:

State DOT Decision-Makers

The enhancements derived for the use of *Clarus* data for maintenance, TOC/TMC, and construction activities include the *Clarus* data for planning of approaching events, improved forecasts, site-specific evaluation of conditions, and the ability to report changing conditions during an event. The enhanced reliability of the quality-controlled data provides a greater comfort level for all users within these areas of responsibility. Maintaining the route during winter events will be enhanced as changing conditions reporting assists management in directing assets. Scheduling and planning is again improved during construction activities directed at specific activities that relate to weather's effects on materials and TOC/TMC management of traffic activities, emergency services and maintenance is improved through access of a greater number of both site specific data and regional data for event tracking, planning, and directing activities.

Weather Service Provider

The available benefits of *Clarus* data is evident to public, surface transportation and general commercial weather service through the enhanced expansion of current weather data sites through given regions and across geo-political boundaries. Current modeling activities, site-specific forecasts, and even regional

forecasts will be enhanced through the absence of data "black holes" across a given area. The addition of data across state lines further enhances forecasting capabilities by providing a seamless extension of the region outside the primary focus enabling forecasts to take into account changing conditions rapidly approaching the area or region of concern. Reliability of the data is of primary concern at this point with *Clarus* data answering this concern through the quality control aspect of the system. These benefits, while directly applied to the weather service providers, are realized to a higher degree through the improvements within the forecasts provided to industries across the U.S. that rely heavily upon weather information within their decision making process.

Traveler

Public: Being located in a winter climate and having an awareness of the hazards posed by potential winter conditions was clearly noted in the responses as the more hazardous weather related events and were highlighted as being of greatest interest to the group.

Commercial Vehicle Operators: The benefit to CVO is anticipated at the vehicle operator level and at the fleet maintenance level. Providing vehicle operators with improved route-specific road weather and road condition information, it will be possible to better manage the en-route decision making of the operators. By providing fleet maintenance personnel with current observed and forecast weather and road condition data, it will be possible to better coordinate shipment timing and route planning in support of just-in-time methods of goods and produce shipments. This will provide economic benefit not only to the CVO but also to the parties to which the CVO actions are responsible.

Non-DOT State Agency Decision-Maker

Emergency management: By integrating *Clarus* System provided ESS data with other surface weather observations and presented in a multi-state framework, the emergency manager has a scoping tool for performing emergency response to situations both transportation and non-transportation related. This provides the ability to conduct emergency management operations in a manner to respond to both present road weather-related and those predicted to occur. The *Clarus* System data also provides an extended observing capability that will provide assistance in emergency management decision-making that transcends those involving transportation.

Public Safety: With limited assets, planning for events represents one of the primary focuses of public safety. Response to accidents, stranded motorists, or evaluation of areas due to specific conditions is greatly facilitated by advanced information. *Clarus* System data provides this additional intelligence not only of weather related events, but also of the movement and degree of each event as it approaches through the extended observing capability as mentioned above. This provides the ability to plan for pre-positioning of personnel and equipment or, more importantly, the direction of evacuation if necessary. Of greatest importance to public safety is the reliability of the data, resulting in a high degree of importance of the quality control aspect of the *Clarus* data.

Non-Surface Transportation Weather Information Consumer

Secondary to use for travel purposes, the public has demonstrated an interest in *Clarus* data for decision-making outside of the transportation network. Schools, recreational activities, and day-to-day agricultural and business concerns are all governed by the weather to some degree. The *Clarus* data can provide enhanced information detailing both current and expected conditions over the short term. The extended observing capability already mentioned earlier is again of value to segments of users. Utilizing the information in a number of formats can provide insight for planning activities, enhancing scheduling, and increasing efficiency of materials and funding. For example, in agricultural alone, the application of some chemicals may cost as much as $20,000 per application. When this chemical requires six hours of

dry application to be effective, being able to plan for rain could save both time and money. The *Clarus* System allows for the use of data to be issued as planning tools as well as increases the availability of weather site locations across a given region, regardless if the location of interest is near a state line.

Research Community

Across the country, research in a number of fields are limited by a single uncontrollable variable, that of weather. *Clarus* can provide a greater coverage of weather for these organizations, through the consideration of weather factors within their operations. With greater coverage of a given region and the elimination of geo-political boundaries relative to the data, federal and state agencies, universities, and even the private sector can eliminate the guess work of weather within areas or regions that current allow access to very limited data sources. Over time, this additional data can reduce the need to estimate results for a given action. Federal and State agencies can plan and evaluate events, meetings, or work related activities to maximize participation by a given group or groups. Both government and the private sector may enhance their activities as well, again with planning that considers weather information.

7.1.2 Limitations/Disadvantages

It is important to recognize that no system or technology is perfect for every circumstance. Depending on the technologies utilized in deploying the services found within the demonstration, there will be variations in the quality and performance of the services. Further, the demonstration depends significantly upon the provision of forecast weather and road weather conditions. As the science of weather forecasting is not exact and will vary depending upon the severity and complexity of weather conditions that occur, there is the potential for considerable variability in the performance of the prediction efforts.

The demonstration concept suggests a significant level of inter-agency participation and sharing of data and information. The reality will likely be that the information technology policies and procedures in place within each state may limit the capability and willingness of states to provide access to state information. These limitations may be based both on technological limitations and on liability-related concerns.

Technology-based systems are simply applications of technology to solve problems or improve operational characteristics. It takes humans to effectively implement technology, and oftentimes management and operations policies are not modified to take advantage of a technology-based system's capabilities.

An additional limitation is the cost of the fully developed demonstration system. The availability of federal funds to support the high-level of ITS integration in the demonstration concept will largely determine the success of the program. Generally, it is cost prohibitive to build every desirable function into an initial system. This means that some system functionality, including those mentioned in this document, may not be implemented in the demonstration. This may cause frustration from those system users who must wait for their desired functionality.

Another potential disadvantage revolves around customer expectation. As with many ITS systems, once implemented, the customer becomes accustomed to a higher level of service. In the case of the North/West Passage *Clarus* Regional Demonstration, it is likely the end-user either within a state agency or an outside user will come to expect and rely on the enhance capabilities afforded during the demonstration. Identification of sustainability of the demonstration activities beyond the demonstration period will be necessary during the system design of the demonstration.

7.1.3 Evaluation Metrics

The evaluation metrics and procedures for assuring the effective demonstration of the concepts provided in this study include the following.

- Quantity of data provided to decision makers.
- Number of accesses or data requests of new services resulting from the demonstration.
- Number of subscriptions for automated alerts and notifications.
- Percentage of up time for the regional systems resulting from the demonstration.
- Results of a survey of system service users as to their experience with, and opinion of, the demonstrated services.
- Number of agencies participating.
- Number of multi-state road weather coordination events that occur.
- Number of 511 users.

Section 8. Other Considerations

The North/West Passage *Clarus* Regional Demonstration involving eight states will present a significant coordination and communications challenge that is both exciting and daunting. The level of institutional challenges will demand that a high degree of agency representative involvement in the system design be achieved. This will be necessary to fully explore and delineate the institutional issues and legal restrictions that might arise.

Appendix A – Acronym List and Glossary

AASHTO – American Association of State Highway and Transportation Officials
AM – Amplitude Modulation
ATIS – Advanced Traveler Information System
DMS – Dynamic Message Sign
DOT – Department of Transportation
CARS – Condition Acquisition Reporting System
CVO – Commercial Vehicle Operator
ESS – Environmental Sensor Station
FHWA – Federal Highway Administration
FM – Frequency Modulation
GIS – Geographical Information System
GPS – Global Positioning System
HAR – Highway Advisory Radio
HTML – HyperText Markup Language
ISO – International Organization for Standards
ITS – Intelligent Transportation System
MDSS – Maintenance Decision Support System
NetCDF – Network Common Data Format
NOAA – National Oceanic and Atmospheric Administration
NWS – National Weather Service
PDA – Personal Data Assistant
PFS – Pooled-Fund Study
RCRS – Road Condition Reporting System
RWIS – Road Weather Information System
SAFETEA-LU – Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
STWSP – Surface Transportation Weather Service Provider
SQL – Structured Query Language
TIG – Technology Implementation Group
TMC – Traffic Management Center
TMDD – Traffic Management Data Dictionary
TOC – Traffic Operations Center
TPF – Transportation Pooled-Fund
UML – Unified Modeling Language
W3C – World Wide Web Consortium
XHTML – Extensible HyperText Markup Language
XVG – An SVG-based Macintosh X-client operating system drawing application
XML – Scalable Vector Graphics

Appendix B – User Needs

User Needs Identification

The identification of stakeholders was the first step in reaching consensus on user needs categories. Direct and indirect use of the Clarus system can be applied to a wide audience. On-site stakeholder meetings were held in each of the eight North/West Passage states during summer and early fall 2007 (Table 2). These meetings were arranged by the Project Team Member state where the meeting was held and facilitated by Meridian personnel who led the group discussion. Participants at these stakeholder meetings included a variety of state, public, and commercial interests. Typical attendees included state Department of Transportation (DOT) personnel representing maintenance, information technology, traffic management, and construction; other state agencies including state patrol, emergency management, agriculture; and, weather service providers. Material developed by the North/West Passage team to solicit stakeholder responses was distributed at each meeting and included sample survey questions that would be included on a web-based survey instrument. The information gleaned from the on-site stakeholder meetings indicated, in part, the desire for information that provided advanced notice of travel delays due to weather, improved road condition reporting along Interstate highways, and better awareness of the advisory and control actions taking place in adjacent states.

Stakeholder Meeting Location	Meeting Date
Madison, Wisconsin	July 17, 2007
Olympia, Washington	July 26, 2007
Boise, Idaho	July 27, 2007
Bismarck, North Dakota	July 31, 2007
Cheyenne, Wyoming	August 7, 2007
Pierre, South Dakota	August 14, 2007
Bozeman, Montana	August 16, 2007
St. Paul, Minnesota	October 2, 2007

Table 2. On-site stakeholder meetings

The original *Clarus* ConOps identified stakeholders in a priority order from 1st order through 4th order. This distinction expressed these orders as:

- State DOT decision-makers - 1st order
- Surface Transportation Weather Service Providers -1st order
- Weather Service Providers - 2nd order
- Research Community - 3rd order
- Non-surface transportation weather interests - 4th order

After a review of the interests within the North/West Passage, this ranking was modified to include two additional stakeholder groups – Travelers and Non-Transportation State Decision Makers. The former group consists of both the general traveling public and commercial vehicle operators. All of the North/West Passage states have existing programs such as 511 to provide support for this stakeholder group and are committed to sustaining/improving this support. In addition, all of the North/West Passage states either work or closely collaborate with public safety and emergency management agencies in their

states. While both of these stakeholder groups could fall within the 4th order above, it was felt that these groups are significant to the activities of the North/West Passage states and deserve a higher degree of attention. Both should be considered as 1st order in significance.

Web-Based Stakeholder Survey

Using information from the on-site stakeholder meetings and building upon the information gained in the review of ITS architectures and ITS deployments in the North/West Passage states, initial web-based surveys were developed for the traveler, DOT maintenance, and commercial vehicle operator (CVO) stakeholder groups. The choice to utilize web-based survey instruments resulted from the geographic size of the North/West Passage area and the need to expedite the collection of stakeholder information. These surveys were developed using a web survey tool known as Survey Monkey. The survey instrument was developed to target specific areas of involvement and usage for each of the stakeholder groups. A set of general questions was used at the beginning of the survey to identify geographic areas of interest of the respondent along with demographics and primary weather concern areas. Using a mandatory response question that identified a specific stakeholder interest, the respondent was directed to the survey questions particular to their stakeholder interests.

Upon approval of the survey instrument by the Project Team, the survey was released for access through various methods of interest to the participating states (Table 3). The most popular method of soliciting responses to the survey was through posting the survey on web pages supporting either traveler information or road weather information. Additional survey responses were requested from special interest groups, e.g. trucking associations, etc., through distribution of the web survey address to their membership.

Sponsoring Entity	Survey Posting Method
Idaho	Web survey link distributed to state employees
Minnesota	Web posting pending
Montana DOT	www.mdt511.com
	www.mdt.mt.gov/travinfo
	rwis.mdt.mt.gov
North Dakota	www.dot.nd.gov/travel/travel.htm
	www.dot.nd.gov/divisions/maintenance/511.htm
South Dakota	www.safetravelusa.com/sd
	www.sdtruckinfo.com
Washington	wsdotblog.blogspot.com
Wisconsin	State web page
Wyoming	Web survey link distributed to state employees
Meridian Environmental Technology	clarus.meridian-enviro.com/nwpassage

Table 3. Individual state methodology for survey dissemination

After a three and one-half week period, the web survey had received a total of 1,566 completed responses. The age of the respondents indicated a clear bias towards experienced drivers with an average age of the survey respondents being between 40-50 years of age.

General Motorist (Traveler) USER Group

Sample Group

The General Motorist (Traveler) response group represented the largest survey participant, based on 813 responses identifying as travelers from across the North/West Passage states. Their representation spanned the sample age ranges, while 81.3% were at 41 and above, 10.3% were 31-40 with 7.5% 22-30 and 0.9% were 21 and under. This range of ages suggests a diverse viewpoint of experiences, with a clear indication of experienced drivers (based upon an assumption of 18 years as initial driving age).

The survey responses provide an insight into a wide array of traveler experiences, what road weather information was currently used or sought, and which would be of use in the future. The opinions expressed by this survey group related directly to the traveling public's desire for safer travel during both daily excursions and occasional trips.

This sample group represented individuals who generally commute 25 miles or less per day (73.9%) or commuted 25-50 miles per day (14%). Commuters who drove more than 50 miles per day comprised 12.1% of the sample. Within this group, 66.2% averaged more than one trip per month each year that was planned and did not include daily commutes where 75.7% of which were for recreation or vacation. Traveling beyond their home state from 1 to 10 trips per year was prevelant with 77.1% of the respondents indicating this occurrence.

Travelers were aware of travel information sources via telephone and/or websites. State web pages were the dominant source (85.8%), followed closely by 511 telephone traveler information systems (72.5%). The awareness and useage of adjacent state web pages for travel information was common with over half (58.6%) of the respondents indicating an awareness of this information availability.

Current Use and Access

Being located in a winter climate and having an awareness of the hazards posed by potential winter conditions was clearly noted in the responses as the more hazardous weather related events were highlighted as being of greatest interest to the group. The participants were asked to rank 17 of the most common weather events encountered by travelers as to their importance on a scale of 1 to 10, with 10 representing a key factor in their travel planning process. Blizzard conditions, sleet or freezing rain, freezing drizzle or fog, blowing snow, and moderate to heavy snow represented the major concern for the bulk of travelers as seen in Figure 15. These dominant winter hazards were followed closely by flooding, bridge or road frost, tornadoes, high winds and extreme cold that were also predominantly considered to be extreme events or a serious hazard to driver safety, such as water covered roads or slick highways due to frost.

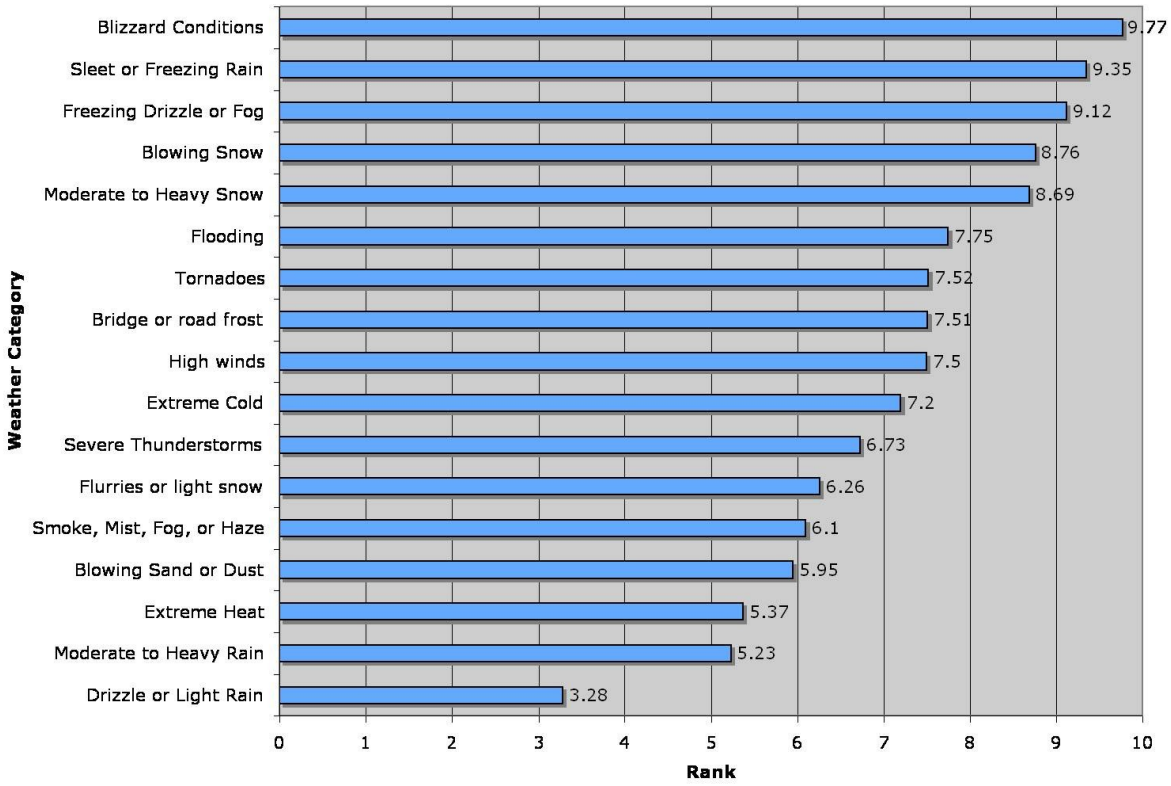

Figure 15. General Motorist Traveler weather concerns.

Safe travel during both daily commutes as well as planned trips was of greatest concern to the sample group. This included weather events that were viewed to hamper travel, for example resulting in slow moving traffic, closed roads, etc., or create dangerous conditions. The concern for weather events that decrease visibility for the traveler was of importance.

The type of weather information used revealed the strong desire for localized weather information to support their decision-making activities. Site-specific weather information led the usage with 87.9% rated at very useful, followed by map-based regional weather information at 82.7%, and National Weather Service watches and warnings with 79.8%. Current camera images along a given route and local ESS weather conditions completed the top five weather information sources with 73.7% and 62.0%, respectively. The use of weather radar closely followed at a ranking of very useful at 60.4%. While not the first source for many, almost as important to these sources were local weather station conditions, HAR, and satellite images. Marine information sources were rated at 78.7% as not useful or not applicable for the entire survey population. However, when reviewed for the State of Washington where marine traffic is most predominant, the usefulness of the information became 34.7%.

The dominance of the web and broadcast media was seen with the preferred communication methods being the internet (World Wide Web) at 98.7% and television and radio at 82.8%. A distant third was e-mail at 49.6% and telephone at 45.2%, with all remaining options at 30.8% or below.

The sample group's response to current communication methods focused on the internet with 96.3% rating it as "very effective" to "moderately effective" in accessing the available information. Television

and radio followed at 84.1%. These selections, however, far outpaced the group's remaining choices of access with telephone, e-mail, agency radio, company intranet, pager, and fax ranging from 57% down to 18.1%.

This was evident in how they access information for pre-travel planning with 96.4% using web pages, 56.7% television, and 45.8% radio. Of course the focus shifts while in en-route with radio leading the choice of source at 81.6% followed by electronic message signs at 63.5%. When addressing 511 useage, it is important to note that a few of the participating states did not have 511 during the survey. The responses for 511 useage were ranked as "Always" or "Frequently" at 33.1% for road conditions, 24.5% for weather information and 15.6% for construction. The concern and/or demand for travel time and traffic information was not at present a significant issue with the survey respondents as useage for these categories was below 5%.

When identifying factors of major importance in considering travel, current road conditions and forecasted weather conditions were listed as the two most important issues with 62.3% and 57.4%. Forecasted road conditions and current weather conditions came at 56.4% and 54%. When the same question was asked in regard to information during travel, forecasted and current weather conditions changed places of important; however, the difference between these four were very small ranging between 79.2% and 64.4%. The top three sources of information during travel were local radio, satellite radio, and 511 or telephone-based information ranging from 88.4% to 68.1%.

Future Expectations

Provided that some of the issues listed are improvements and changes made to facilitate greater ease of use and access with more mobile means, questions were asked to determine if travel behavior could be altered. As with the majority of the survey respondents, timeliness and accuracy of current data was listed as most important with 60.4% and 52.8%. The availability of the data was expressed at 39.4%, and the relevance at 35.4%.

Should road pavement forecast conditions be available, 78.7% stated they would use it for route selection or alternate route evaluation with 75.4% agreeing to make a "travel" or "no travel" decision and "alter departure time" (72.6%). This did not change when offered alerts of changing condition along a specific route once travel has begun, except that 63.8% stated it would also be used to determine where and when to stop the trip.

The group was asked to envision their preferred source of road weather information given a future of a more mobile information environment. Radio was still ranked at the top with 60.9%, followed by in-vehicle displays at 49.7% and television at 36%. However, a number of comments listed internet access with the vehicle as their preferred method suggesting a visual requirement of a map based display.

Conclusions

This group was a significant section of the sampled stakeholder population that prefered maps to instructions and automated alerts to self-check systems. This group, however, was not well represented by travelers of extended distances and therefore may have some limits in interpretation. Currently, this group was focused more on pre-travel information. While there was a desire for en-route information, it still represented current road conditions and weather information rather than a strong interest in forecasted conditions. This suggests that considerable growth can be achieved in the future with the incorporation of forecast road conditions and weather information into their decision making process. This transition will take place only when the users are convinced that the data/information exhibits timeliness, accuracy, and utility to their specific their needs.

Commercial Vehicle Operators USER Group

Sample Group

The response from this segment of stakeholders during the sample period was commendable. A sampling of 108 commercial vehicle operators (CVO) related interests were received. Of the group responding, their representation of the industry was divided into 55% long-haul drivers, 34% short-haul drivers and 11% local route delivery. While the participants covered all driving age ranges, over 83% represented drivers 41 years or greater and suggests a high level of commercial vehicle operations experience.

The focus of the survey was to try to determine if additional, reliable data provided by the *Clarus* Initiative could enhance the decision-making processes associated with Commercial Vehicle Operations. Highlighted within these responses are specific indications of what is currently used or sought and what could be of use in the future.

Current Use and Access

The more hazardous weather related events were highlighted as being of greatest interest to the group. The participants were asked to rank 17 of the most common weather events encountered by travelers as to their importance on a scale of 1 to 10, with 10 representing a key factor in their decision making process. As with the traveling public, blizzard conditions, sleet or freezing rain, freezing drizzle or fog and blowing snow represented the major concern for the greater part of the commercial vehicle operators (Figure 16), followed closely by moderate to heavy snow and high winds. After these extremes, cold weather events were the focus of the group with bridge/road frost, flooding, tornadoes, extreme cold, and flurries/light snow rounding out the bottom of the priorities.

Of the provided types of weather information, the survey participants were asked to rank the usefulness of a variety of information sources and communication methods of access. Site-specific weather information led the demand with 87% rated at "Very Useful," followed by National Weather Service watches and warnings with 83.3% and map-based regional weather information a very close 3rd with 83%. Camera images of current site-specific events along a given route and radar images completed the top five weather information sources with 78.5% and 73.8%, respectively. While not the first source for many, but almost as important to these sources were ESS data, local weather station conditions, HAR, and satellite images. When "Very Useful" and "Somewhat Useful" were taken into account together, all of the above sources rated above the 92 percentile of current use.

The survey group's response to current communication methods focused on the Internet with 96.3% rating it "Very" to "Moderately" effective in accessing the available information. Television and radio followed at 84.1%. The remainder of options provided significantly less usage with a surprisingly low reliance on company communication methods (22.8%). This was contrary to the face-to-face stakeholder findings with CVO where a strong reliance on dispatch was found to be evident.

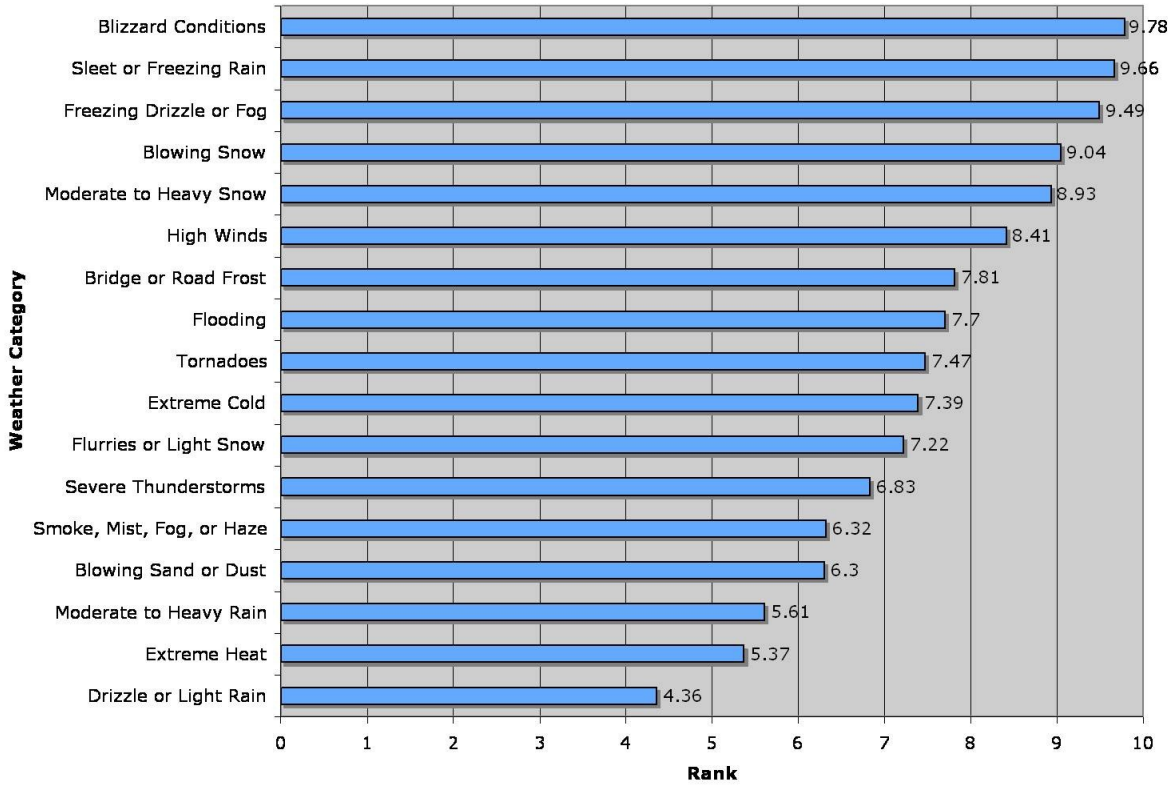

Figure 16. Commercial Vehicle Operators weather concerns

Future Expectations

The sample group was asked specifically about future communication possibilities through a set of questions designed to envision the future of road weather information in a more mobile environment. These questions focused on the type of and access to road weather information in both a current and forecasted view of weather and road conditions as reported by automatic stations and actual reports.

The survey asked which travel information resources were used during planning and en-route activities. The 511 traveler information system had a high degree of awareness (89.7%) followed by 88.7% awareness of state sponsored web pages. The respondents reported a 76.9% awareness of surrounding states web pages, followed by 63.9% of commercial travel information web pages, but only a 62.9% awareness of state sponsored telephone based systems outside of 511.

Planning activities depended heavily on Internet usage with 89% reporting use prior to departure. This was followed by radio (48.6%), television (41.3%), and 511 (31.2%). During travel, updates to the decision process focused on radio at 69.7%, electronic message signs at 55.1%, citizen band radios for immediate eyewitness reports at 48.6% and telephone based system (511) at 39.5%. This clearly indicated a reliance on the human factor of eyewitness reporting on conditions across the roadway for both road conditions and weather information. It is important to note that while citizen band radios may provide current (eyewitness reports) of conditions and that radio and 511 contain forecasted condition, there seems to be a focus on a combination of these being used to provide current conditions (eyewitness reports) and forecasted conditions.

To further examine this concept, the group was asked to rank the specific type of information and their frequency of use of a telephone based system, such as. 511. With a rating scale of "Always", "Frequently", "Occasionally", "Rarely" or "Never", the group was asked to rate specific types of information obtained from the system. Road conditions were cited as "Always" or "Frequently" the main reason for access with 48.6%, followed by weather at 41.6%. Traffic, travel times, road construction, and other information all fell below 20%.

The same scale was then used to the value of web pages providing the same type of information. Again, road conditions and weather topped the list with 87.9% and 83.5%. However, other types of information did move up with road construction at 36.6% and traffic at 28.8%.

Determining more the type of information desired for both planning and during travel, the survey group was asked to provide how they use specific information and its importance to their decision making for both planning and en-route travel. In both planning and en-route travel, current road and weather conditions were the primary focus of the group rated at 75% and 65.4% during planning and 86.3% and 76.2% during travel. However, when asked about the use of more specific forecasted weather and forecasted road conditions, the group's response was reversed. When it came to forecasted conditions, weather was deemed just slightly head of road conditions with a rating of 63.1% and 59.2% for planning and 73.0% and 72% during travel. For planning purposes, all the remaining types of information were rated below 30%, except for travel accident information, which rose to a respectable 42.4%.

In an effort to determine more specific communication systems used during travel, the group was asked to select their top three sources of information. In-vehicle web page access was rated as desired by 54.5% and 511 at 45.7%. This was followed by radio at 44.3% and dispatcher direct contact at 43.8%. HAR rounded out the information source selection with 36.0% while all remaining choices were 29.2% or below.

Focused on future developments and availability, the group was asked to rate specific improvements desired and how these improvements would affect their use and decision-making. On a scale of 1 to 7 with 7 representing the most important issue and ranking the top two indicators; accuracy of both current and forecasted data was overwhelmingly the primary desire with a combined rating of 87.6% followed by timeliness at 85.4% and availability at 70.2%.

The survey also polled regarding the use of specific road pavement data. If the data are available, the group indicated that this information could govern route selection (79.2%). Determining where to travel or not to travel and determining a time of departure was also a significant indicated benefit (68.7%). Whether or not to continue traveling or where and when to stop based upon the availability of pavement data represented 55.6% of the group. The remaining selections were below 13%.

The group was asked to envision the ability to have information on changing conditions provided to them in the form of alerts while en-route and to indicate its importance and how this would affect their decision process. Using the same choices above, selection of route remained the primary focus for the use of the information (82.7%). However, determination of when and where to stop became more important with the alerts (71.4%) and where to travel or not to travel remained virtually unchanged at 68.4%.

With this new option of alerts for certain conditions, the respondents were asked to rate the importance of specific information sets relative to each other. Alerts for adverse weather conditions and changing pavement conditions received most of the interest followed by forecasted weather and pavement

conditions. With the alert option, the focus of CVO changes to forecasted weather and pavement conditions followed by alerts for weather and pavement conditions.

And finally, given the vision of a growing mobile society, the group respondants were asked their preferred choice of information provided cost was no object and availability was assured. In-vehicle display units and satellite radio topped the rankings with 52% and 51% followed by local radio and television.

Conclusions

The sample group indicated that safe travel across the roadway was of primary concern. This included weather events that hamper traveled or created dangerous conditions. The next focus for CVOs was clearly weather events that decrease visibility, followed by events that can make travel uncomfortable. It is apparent that the key interest of this group is continuous movement, limited delay, and knowledge of current and future conditions and events that can afford them options in decision-making.

With all the focus at present on a highly mobile and connected society, the current use indicated we are still very much tethered to certain stationary systems or operations for decision-making. However, the responses also indicate a desire to evaluate the current and forecasted weather and road conditions individually. With advances in telecommunications and this technology moving to more mobile methods of data exchange, the focus of individual decision-making has become highly mobile. Increased use and access of road and weather information in a transit environment will continue to facilitate improved travel decision-making.

It would appear there is a view that information on the website is more current and more readily updated than the telephone based system. While the same type of information was sought, the frequency and reliance on the web with its limited accessibility during travel versus the telephone-based system appeared to currently enjoy a higher confidence level among users.

Finally, the approval of en-route alert capabilities appeared to suggest that with accurate, reliable, and timely information on road weather, travel behavior for this group may be expected to alter specifically during adverse weather and road conditions.

State Transportation USER Group

Sample Group

The state transportation agency stakeholder group was comprised of personnel from maintenance, construction, information technology, and traffic operations/traffic management. A sample of 153 state transportation decision makers was made in the web-based survey. The participants covered all driver age ranges with over 60% representing experienced personnel of 51 years and over, suggesting a high level of state highway maintenance experience. While the survey group included information technology professionals, the responses received from this sub-group was limited to four responses.

Within these responses were specific indications of what was currently used to support daily operations for traffic management, road maintenance and construction and what would be of use in the future for a more proactive approach to system requirements. These decisions related directly to the decision-making processes for a safer travel system along the nation's highway system. The key interests of this group were similar to that of CVO user group, relating to continuous movement, limited delay, and knowledge of current and future conditions and events that can afford them options in decision making.

Current Use and Access

The participants were asked to rank 17 of the most common weather events encountered as a key factor in their decision making process. Consistant with travelers (general motorists and CVO), blizzard conditions, sleet or freezing rain, moderate to heavy snow, freezing drizzle or fog and blowing snow represented the major concern for the majority of decision makers. These events were followed closely by flooding, bridge or road frost, high winds, and light snow.

Current use and the type of information acquired included site-specific weather information, weather radar images, National Weather Service watches and warning, weather satellite images and map-based regional weather information in the top five resources. When "Very Useful" and "Somewhat Useful" qualifiers are combined together, the above data sources encompassed over 97% of the responses for this survey group. It was interesting that the agency provided data, such as ESS and camera images, were in the second tier of information utilized.

Of currently provided weather information types, the survey participants were asked to rank the usefulness of a variety of information sources and communication methods of access. 96.1% rated the Internet "Very" to "Moderately" effective and as the most popular current communication method in accessing available weather information. The Internet was closely followed by the agency's intranet at 77.0%. Agency radio, television and radio, and e-mail round out the top five. These selections far outpaced the group's remaining choices of access with telephone, pager, and fax.

The survey instrument included inquiries on the frequency, type, and the "whats" and "whys" of current use of ESS data in their operational decision-making. The purpose and frequency of use for maintenance personnel included 42.5% for monitoring changes in road conditions, 25.8% to triggering maintenance responses, 17.5% monitors changing condition, while only 13.3% used the data for resource planning activities. The survey indicated that 72.8% of traffic operations personnel used ESS data to monitor road and weather conditions with 9.1% using the data to review conditions in and around accident scenes. It was also indicated that 30.8% of construction personnel focus on pavement and weather conditions with a small percentile using ESS data for resource planning.

The frequency and type of sensors used completes the data useage picture. Maintenance personnel review ESS data daily 40.5% of the time, 21.5% review data 5-15 days per month, and 13.2% conduct ESS data reviews 15-25 days per month on average during a given year. TOC personnel rank their use daily at 60% with another 20% between 15-25 days per month with 53.9% of construction personnel using the data less than 15 days per month and another 25% using it daily. When considering the level of out-of-state ESS data use, it was found that only minor current use was made of ESS from other states. 69.4% of the survey responses indicated that in all cases the use of ESS data from adjacent states was rated at fewer than 5 days per month or never.

In determining the types of information reviewed it was found that air and pavement temperatures were requested the most, followed by wind speed and road conditions rated between 87.3% and 80.7%. Wind direction, pavement freeze point, and camera images followed with 76% and 69%. All remaining sensors were relied on much less frequently. For construction personnel road conditions, air temperature, wind speed and direction followed by precipitation rate were the most used sensors. With TOC personnel, the focus was on camera images as their primary sensor.

For maintenance personnel the frequency and time of year was reviewed with survey participants noting very little difference between regional or statewide data use and emphasizing hour-by-hour site specific data access across areas and very little use of multi-state information. Participants noted that the

predominant time of year for usage was winter (88.4%) and only a small usage difference between fall (74.5%) and spring (74.1%). As for the access methods, the current use of state provided website was found to be a primary source of current road condition information (75.2%) and current weather information (73.6%). For forecasted road condition information, the percentage for the state website dropped to 60% and also decreased for forecasted weather information (68.8%).

Provided information on road conditions, the groups were asked to rank the importance of specific events as to their effects on resources, treatment, or schedules. Snow covered, compacted snow/ice and minor flooding were identified as requiring resource decision-making, while treatment decisions focused on black ice, compacted snow/ice only in wheel tracks followed by the occurrence of passing lane only snow packed. Minor flooding, wet road with standing water and drifting snow were cited as affecting work schedules. This same question was addressed by TOC personnel who discounted everything for resources except closures in other states. Maintenance personnel survey respondents ranked closures in other states very low. During the on-site stakeholder meetings, maintenance personnel responded similarly to their online counterparts, with the exception of personnel located immediately adjacent to a state border. In those situations, the level of concern of neighboring road conditions was significant. TOC personnel focused on control actions and work schedules ranking minor flooding and any snow compacted road issues as of primary concern. Black ice, neighboring state road closures, and snow covered roadway over 1" present work schedule concerns for TOCs.

As for the accessibility of information, internet, television / radio, intranet and e-mail were the access methods considered most effective with rankings from 97.5% to 69.8% for "Very" and "Moderately" effective. Agency radio followed these ranking with limited interest for telephone, pagers, and faxed information. The access to current and forecasted condition data was examined for ESS observations and forecasted weather data where ease of use, availability, confidence and usefulness were assessed. The group emphasized the importance of forecasted weather data having a high ease of use as the most desired followed closely by the availability of current conditions a close second. Both features were in the 90+ percentile for high and medium rankings. However, usefulness and confidence of forecasted weather data and current ESS conditions were cited as problematic and needing improvement. The comments offered by respondents indicated the quality control concerns of ESS, lack of availability of the data, and the reliability and appropriateness of the forecasted weather conditions as being a significant concern. When asked about the satisfaction level of ESS data and ESS related weather products, the group ranked ESS data accuracy, road weather forecast accuracy and timeliness at only 73% and below. Site-specific information was considered as to its usefulness in the decision making process both directly from ESS and forecasted data. The usefulness of the air temperature, precipitation, and wind direction and speed ESS and forecast data was 66% to 64%. Visibility and pavement conditions responded lower, falling into the 50th percentile.

Future Expectations

Considering the increased use of mobile data collection and wireless communications, the future use of ESS and forecasted data will evolve quickly. To gain insight into these future uses given a continued evolution of technology, questions were posed to determine the acceptance of these technologies. This was presented as an open-ended question and received a number of comments. The focus was on mobile access, advanced notification, and cameras. Vehicle information systems, Internet, global positioning satellite (GPS) weather related links, personal data assistant (PDA) access, and even television and radio enhancements for notification were listed. When asked if improvements were made to improving availability and access to ESS data how often ESS data would be accessed, 41.2% rated access at 15 days per month or less and 9.4% everyday. This represented a slight increase of use with 5-15 days moving from 12.1% to 20%, 15-25 days moving from 6.5% to 10.6%, and everyday from 7.3% to 9.4%.

Conclusions

The main issues appeared to be timeliness and accuracy. These two issues represented the major concerns that hamper recurring use of ESS data. Once this is resolved and confidence builds, data accessibility and frequency will become the primary issues. Accessibility from a number of systems and using a number of methods that may exist only on the drawing board today will become the primary focus for improved utilization in decision-making. Site-specific information was still the key focus of these decision makers, from specific sensor data to camera images and forecasted site-specific weather information. These data will continue to assist in planning everything from resources to treatment selection to work schedule adjustments. It appears from the results of the information provided by this group that while ESS and site-specific forecasted weather information effects these decision makers today to a significant degree, behavior changes and greater adoption of ESS data and forecast information is possible with road weather observing and forecasting improvements.

Weather Service Provider USER Group

Sample Group

The weather service provider stakeholder group included the service providers within the public and private sector who provide weather data and information to a variety of surface transportation and related stakeholders. This group also included the road weather service provider community that was generally a significantly smaller subset of the broad weather service provider community. Thirty-six participants from six of the eight participating states have completed the survey, with an additional response received from someone outside of the region. Montana held the majority of survey participants at 22 of 36 total completed surveys (61.1%). Only half of the survey participants responded to their primary work area. However, of the Montana indicated responses the great majority was from National Weather Service personnel. Similarly, National Weather Service personnel in South Dakota represented the majority of responses for that state. Of these responses, 72.2% were involved in public weather services, e.g. National Weather Service, 11.1% work for surface transportation weather services and 16.7% associate with other commercial weather services. Sixteen of thirty-six respondents, 44%, were 61 years old or older, giving the impression that almost half of our user group responses were management and decision makers.

Current Use and Access

The following graph provides the average ranking on a scale of 1 to 10 (with 1 being not important, 10 being very important) of the 17 listed weather conditions. With this group of users, dangerous weather situations are most important in their decision-making processes. Represented in Figure 17, blizzards, sleet or freezing rain, freezing drizzle or fog, blowing snow and moderate to heavy snow all ranked high on the scale of importance. Additional weather that affects the public, such as tornadoes, high winds, severe storms, and flooding, followed closely behind. Again, 72.2% of the respondents work for public weather services, and these top nine conditions play a large role in public safety. These nine conditions indicate some of the National Weather Services' most hazardous weather warnings and advisories.

Many avenues were available to access useful road weather information for weather service providers. There were different products and methods available, and many ways to access these data sources. This group finds site-specific weather information and National Weather Service Warnings to be very useful in supporting their decision-making, both receiving 90.6%. Next important would be map-based regional weather information at 84.4%, followed closely behind with weather radar images at 82.4%. Of slightly lesser importance were camera images (78.1%) and weather satellite images (74.3%).

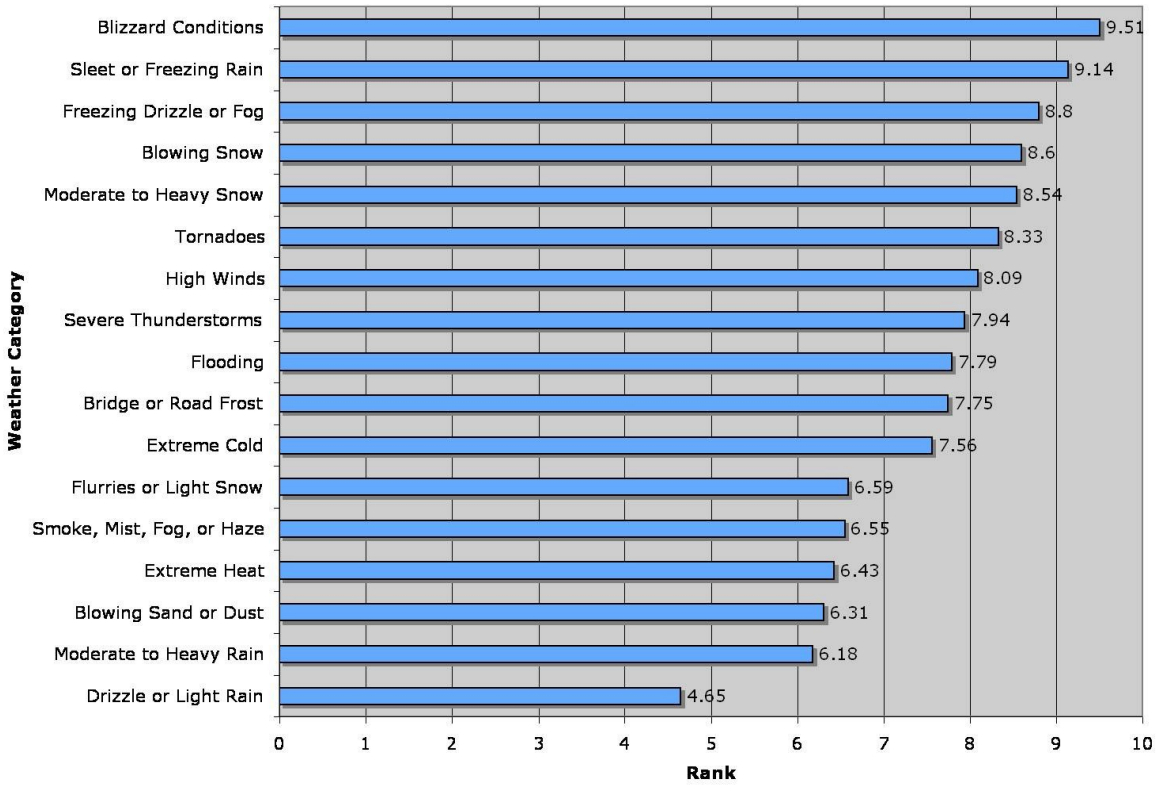

Figure 17. Weather Service Provider weather concerns

To get to information that users find necessary, the Internet rates as the most effective way at 94.3%. Television was ranked the second most effective way of accessing weather information at 72.7%. Internal sources such as agency radios and intranet were also found useful with this group of respondents at 45.2% and 31.3% respectively. Telephone and email sources followed close behind in accessing information at 31.3% and 30.3%.

The most popular products provided in regards to road weather decision-support from this group of users was weather alerts at 88.9% and road condition alerts at 72.2%. Site-specific weather observations, regional weather forecasts and site-specific weather forecasts followed behind at 66.7%, 61.1% and 55.6% respectively. Other products such as road weather support guidance and forecasts tailored for specific road interests ranked much lower at 22.2% and 27.8% respectively. The low ranking and the fact that only 18 of 36 survey participants responded to this question reflected the functional differences between the respondents who were actively involved in road weather services and those who were not. When considering only surface transportation weather service providers, the road weather support guidance and forecasts tailored for specific road interests ranked much higher at 100% and 100%, respectively.

To assist weather service providers in making these products, the majority of respondents (16 out of 36) replied with road condition reports and data from other networks, both receiving 62.5% of the responses. Observations from the national data network were also deemed important at 56.3%. However, typical general forecasting methods such as government numerical models and surface and upper air analyses

were tied at only 37.5% of the responses. Typically, these products only assist in road weather forecasts, so these results were not a surprise.

Future Expectations

When looking ahead to the future integration of additional data within weather service operations, most of the 16 survey participants replied with current weather databases (68.8%), weather forecasting processes (56.3%), and pavement condition databases (50%). When asked if this additional data would impact their pavement related weather support services, 81% stated that it would either greatly improve or somewhat enhance their services. No one thought that the additional information would negatively impact the services that they provide.

Prior quality control of additional information in the future was not as important to most of the surveyed individuals. Automatically removing flagged data and monitoring flags but not removing data each received 18.8% of the votes. However, 56% stated that they would not use quality check flags, indicating that they may not trust the control checks, and would still perform their own checks before integrating information into their systems.

In regards to using information provided from moving vehicles, users would be optimistic but cautious in using it, with 43.8% stating that they would want to monitor the data before incorporating it into existing data processing schemes. Only 18.8% of users polled would not be interested in using this possible information.

Envisioning the future, new technology may be found as useful as current available sources to obtain road weather information. In-vehicle display systems, satellite radio, AM/FM radio and televisions were deemed equally important at 52.6% with this survey's participants. One individual commented that having in-vehicle displays would be wonderful to have, but the individual would want some type of cell phone-based system for his bicycle. Cell phone text messages were rated at 21.1%, showing that even though a large portion of the public uses cell phones on a day-to-day basis, it is still not their ideal way of obtaining information.

Conclusions

This group of users routinely acquired, managed, archived, and repackaged weather information for a variety of purposes and industries. The primary source of weather data was the National Weather Service. The focus of the survey was to determine if their products, services, or processes would change with the addition of ESS road weather data provided by *Clarus* and how the quality check of the data may affect its use. While a number of members of the group indicated that changes to their products and services may come slowly at first, the results of verification of the *Clarus* quality checking process will be crucial before adoption of the quality check flags will be accepted while others would continue to prefer to quality check the data themselves.

While camera images were ranked lower in comparison to other methods of weather information, a comment was made that camera image coverage was important, suggesting areas that could use greater coverage; even though the feeling was that most areas were being covered well. Although not most important on the stakeholders' list, ESS weather conditions and other local weather stations were still found to be 'somewhat to very useful', and did play a large role in the overall decision-making process.

Comments referencing improvement in the frequency and accuracy of ESS suggest that if improved this would generate greater reliance and use of the data. However, even with the doubts evident within the survey results, suggestions of more ESS stations, included statements indicating a general feeling that the

efforts of Clarus would not only increase the amount of information, products and/or services available, but can also help improve the quality of weather information already available.

Non-Transportation State Agency USER Group

Sample Group

The response from non-DOT state agency decision makers across the Northwest Passage had been limited and would have been preferrd to be greater. Fifty-eight participants from the eight participating states completed the survey, with an additional response received from someone outside of the region. Forty-four of fifty-eight individuals responded to their primary work area, with 84.1% working in public safety and 15.9% working in emergency management. Montana held the majority of survey participants with 29 out of 59 completed survey responses (49.2%). Wisconsin was close behind at 29.3% participation. The majority of the respondents were 41 years old or older (76.8%), with the largest age category being between 51 to 60 years old (41.1%).

Current Use and Access

Seventeen weather conditions were evaluated on a scale of 1 to 10, with 1 being not important and 10 being very important. These individuals found dangerous weather situations most important in their decision-making processes. Blizzards, sleet or freezing rain, freezing drizzle or fog, moderate to heavy snow, and blowing snow ranked very high on the scale of importance, as demonstrated in Figure 18. Additional weather that impacts the general public, such as flooding, bridge and road frost, tornadoes and high winds followed close behind.

This stakeholder group indicated that there were many resources available to support decision-making. Over the past year, 59.1% non-transportation agency decision makers were moderately satisfied with the weather information they had available. They stated National Weather Service warnings to be most useful in their decisions at 91.2%. These users also found weather radar images and site-specific weather information to be very useful, both ranking at 84.5%. All of the supplied categories of road weather information were found to be somewhat to very useful, with combined average percentages in the 90+ percentile. There was one exception with marine information, as most users found this not useful. This was not surprising, since our survey region is mostly landlocked.

In assessing the usefulness of information, the majority of users found the Internet to be the most effective at 86.2%. Television and radio were also very effective ways at 63.2%. Telephone and email methods were at least moderately to very effective with this group, with combined percentages of 68.4% and 51.7% respectively. Faxes seemed to be the least desirable method of accessing road weather information, with users finding it marginally effective, if not completely ineffective.

When using ESS data, 20% specifically monitored changing road conditions. Fifty-three percent monitored changing road and weather conditions and trigger alerts to changing road and weather conditions. Seven percent of respondents used ESS in a different way or not at all. Nearly half of survey participants, 47.7%, used ESS practically every day, with 86.3% using ESS at least 5-15 days or more each month. Concerning the usage of sensors available on ESS, road condition information was routinely used at 88.1%. Other routine sensors were air temperature (66.7%), precipitation rate (58.5%), wind direction (57.5%), and wind speed (57.1%). Most available sensors were at least occasionally used, except for water depth on road, chemical factor, and ramp temperature, as these sensors were either never used or not available to at least one-fourth of this user group. However, from all the sensor information that was not available to each user, 32.3% would use this extra information fewer than 5 days a month.

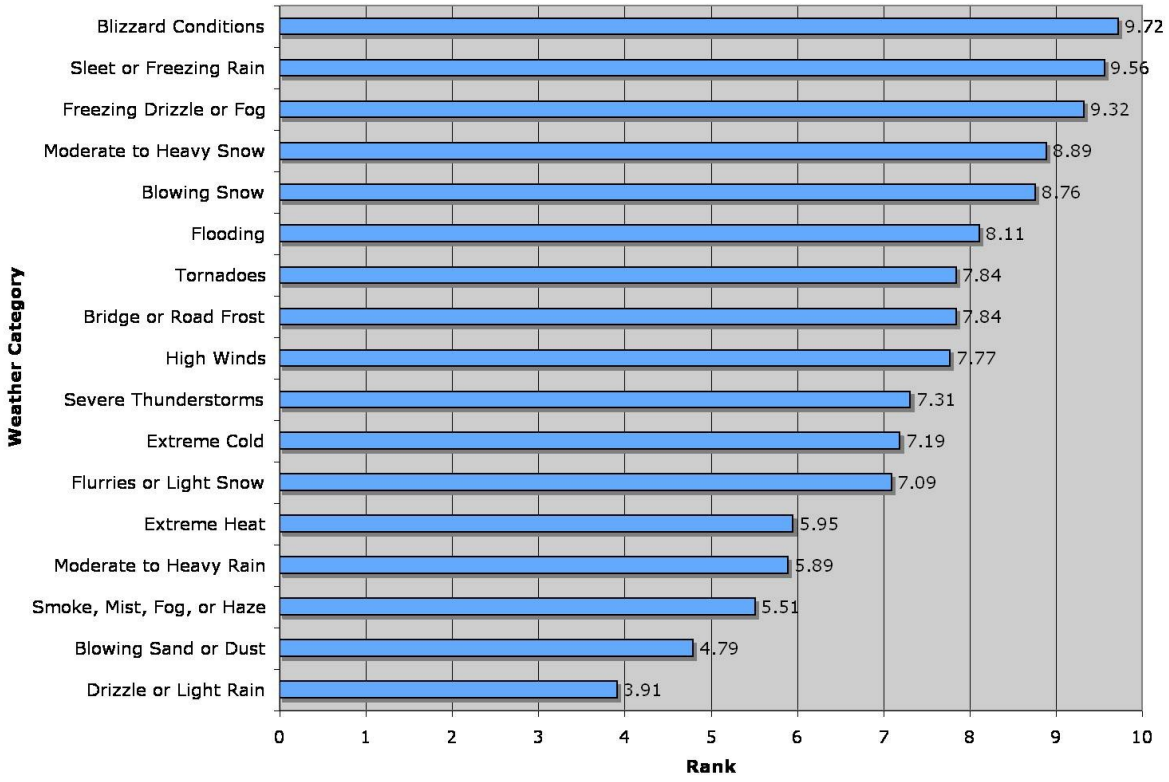

Figure 18. Non-DOT State Agency weather concerns

It seemed that the majority of the users do not frequently visit other states ESS data, with 41.9% using adjacent state information less than 5 days a month and 25.6% never using surround states data. The biggest concern with ESS data appeared to be the timeliness of the data. Fifty-two percent were moderately to very concerned with data timing, with 43.9% moderately to very concerned with the quality of data.

This user group routinely checks ESS to make decisions within their local area (81.4%), and for their entire state (48.8%). However, ESS outside of the user's state was less frequently used, with nearly an equal distribution of use levels across the board. Other weather information sources that were routinely used were television (61.9%), National Weather Service (57.1%), and road conditions reported by ESS (55.8%).

The majority of users check their state's road weather web pages routinely for weather (86%) and road conditions (84.1%). Other conditions such as traffic and construction were checked, but not as frequently as the two previous conditions. When considering adjacent states, weather conditions were most looked at on a regular basis at 29.5%. Other information such as road conditions (50%), traffic (78.5%), construction (72.1%). and observed travel times (87.8%) were seldom or never used with most of the respondents.

Weather related road conditions were identified to have major impacts on transportation and transportation-related decisions. When making these decisions, this stakeholder group stated that compacted snow and ice-covered roads have a major impact (86.4%), with snow-covered roads of one inch or more following closely behind at 84.6%. Black ice and drifting snow on road also have a major impact on decision making with this group at 79.1% and 77.3% respectively. Fifty-two percent of users said that adjacent state road closures had minor impact to no impact on their decisions.

Future Expectations

When looking towards future improvements in available weather information that could change operational decision-making, the comments were scattered across many thoughts. One individual stated that improved accuracy of forecasts, such as start/end times of a storm and total precipitation accumulations, would allow for better decision making and cost savings. Additional cameras and improved sensor accuracy were also mentioned, along with needing to know potential road closures across the state up to four hours in advance or more. This comment was to improve travel planning, as this individual stated that there was no reason to travel across the entire state if the interstate would close half way.

As technology advances and changes in the future, this user group would like to see in-vehicle display systems as their preferred source of road weather information (50%). One comment received stated that in-vehicle systems that could allow contact between counties would be desirable. Forty-five percent stated that television was also a preferred source of this information, with AM/FM and Satellite radios both receiving 35.7% of voter preference. Survey participants also commented that the Internet was still a very popular and necessary way to receive information, and using the Internet in vehicles would be preferred.

Conclusions

Non-transportation state agencies' main concerns were how to better advise the travelers and keep everyone safe on the roads. In a response environment of Highway Patrol and Emergency Management, response to or evacuation of an area appears to be key, with the focus on current and forecasted road and weather conditions. Reliability of data from ESS was noted as very important as well as to view other states ESS for planning purposes. The use of cameras as part of the data was no different here than in other user groups and was used to validate the ESS data received. Timeliness and reliable concerns suggested that if these issues were improved, this group would use the data increasingly over time in decision-making activities.

General Consumer USER Group

Sample Group

The general consumer group was designed to include people interested in weather information from a number of professions including the agriculture, energy and education sectors. The survey was designed to solicit current use and expectation from this wide range of users who were traditionally outside the transportation industry and to determine how improvements in the weather information might affect their decision-making. The response from this segment of stakeholders was good with a total of 115 respondents. The age groups represented were 33% at 51-60, 24% at 61 and above, followed by 21% at 41-50 and the remaining 22% at 40 and below.

Current Use and Access

While the results of current concerns about specific weather conditions had some similarities to that of travel-focused users, there was a shift more to the potential damages that could be caused by weather conditions. The more hazardous weather related events were highlighted as being of greatest interest to the group. The participants were asked to rank 17 of the most common weather events as to their importance on a scale of 1 to 10 with 10 representing a key factor in their decision making process. Figure 19 illustrates blizzard conditions, sleet or freezing rain, freezing drizzle or fog and blowing snow as primary concerns for non-traveling weather information consumers, followed closely by moderate to heavy snow, tornadoes, flooding, extreme cold and high winds; all of which may cause damage to existing assets of energy or agriculture groups. Severe thunderstorms, bridge or road frost, and extreme heat had both the potential to cause some damage or problems in production in both energy and agriculture. The remaining weather conditions, while still garnering some interest showed a much-reduced interest along the line of visibility related weather conditions for non-transportation related decision-making.

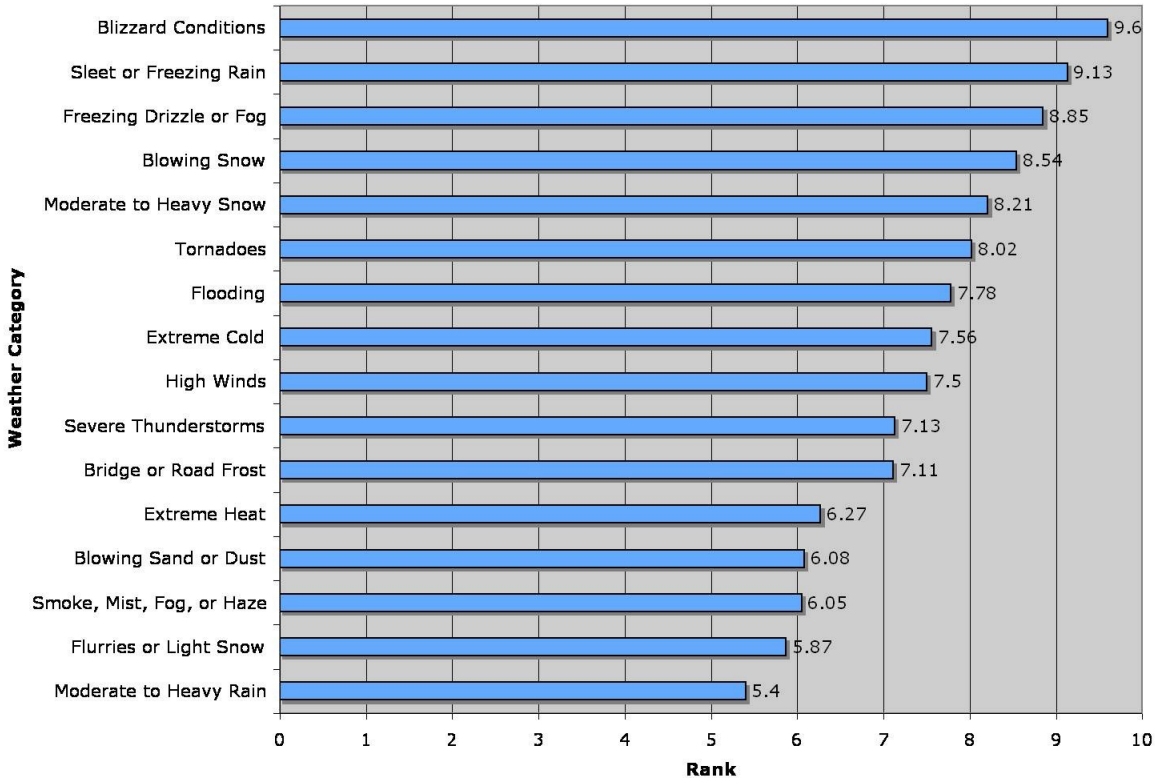

Figure 19. General Consumer weather concerns

Of currently provided types of weather information, the survey participants were asked to rank the usefulness of a variety of information sources and communication methods of access. Site-specific weather information led the demand with 88.5% rated at very useful, followed by National Weather Service (NWS) watches and warnings with 85.8% and map-based regional weather information a very close 3rd with 81.3%. Camera images of current site-specific locations and local ESS reported conditions completed the top five weather information sources with 66.7% and 61.3%, respectively. Radar and satellite images round out the selections ranked above the 50th percentile. When "Very Useful" and "Somewhat Useful" were taken into account together, map based regional weather information took over

the top demand with a ranking above 99%, followed by site-specific weather information and then National Weather Service watches and warnings. Marine information sources were rated at 64.0% as not useful or not applicable for this sample group.

The sample group's response to current effective communication methods focused on the Internet with 100% rating it "Very" to "Moderately" effective in accessing available information. Television and radio followed at 85.7%. This corresponded well with the stakeholder group's primary access methods when at home or office as well. Home or office access listed the web pages at 87.3%, followed by radio at 70%, and television at 60.9%. However, in both questions these three selections far outpaced the remaining choices of telephone, e-mail, agency radio, company intranet, pager, and fax. For access at home or office the lowest rated methods included 511, satellite radio, agricultural weather networks, and pagers. Mobile access naturally focused on radio at 93.6% and electronic message signs at 49.1%.

Future Expectations

As to future expectations of weather information availability and use, the non-transportation general consumer group's questions were focused less on travel and directed more at weather related decision-making. The current effectiveness, use, and access indicated this stakeholder group uses and relies on limited available weather sources that are primarily web-based. Current road and weather information was still favored over forecasted conditions in providing a current understanding of the weather and its effects on surrounding elements as it related to the roadway. In other words, it appeared these non-transportation decision makers track the effects of current weather conditions on the roadway and individually evaluate the potential effects upon their area of concern. While the access issue is still tied to limited data sources to determine the information necessary to make weather related decision, these users did foresee a future where weather information is more accessible and reliable.

Assuming advances in telecommunications and advancements in weather forecast technology, the survey respondents were asked specifically about future possibilities through a set of questions designed to envision the future use of road weather information in a non-transportation decision process. These questions focused on the type of and access to road weather information in both a current and forecasted view of weather and road conditions as reported by automatic stations and actual reports.

Focusing on future developments and access, the group was asked to rate specific improvements and how these improvements would affect their use and decision-making. On a scale of 1 to 7, with 7 representing the most important issue, ranking the top two indicators; timeliness of both current and forecasted data was overwhelmingly the primary issue with a combined rating of 84% followed closely by accuracy at 82%. However, unlike other user groups, relevance was viewed as the next important improvement rated at 66.4% with availability close behind at 62.2%

The group was asked to envision the ability to have this information provided to them in the form of alerts while en-route should conditions change and how this would affect their decision process. Using the same choices above, selection of route remained the primary focus for the use of the information at 82.7%. However, determination of when and where to stop became more important with 71.4% and where to travel or not to travel remained virtually unchanged at 68.4%.

Finally, given the vision of a more mobile society, the group responded that radio would continue to be the primary method for access (68.6%) followed by in-vehicle display units (49.5%).

Conclusions

While the goal for these users was to focus on use of the data not related directly to the decision-making processes for safer travel, but the extended use of the data for non-transportation related decision-making processes, it would be reasonable to assume that some respondents did not make this distinction between the survey instruments. The responses related closer to those focused on travel than to the use of weather for energy, agriculture, or education.

Research Community USER Group

Sample Group

The research community included both transportation and non-transportation research stakeholders. These stakeholders utilized weather and road condition information to support basic and applied science and engineering research activities. Thirty-two participants representing five of the eight participating states completed the survey, with additional responses received from outside of the region. Montana held the majority of survey participants at 22 of 32 total completed surveys (68.8%). Thirty-eight percent of the survey participants were between the ages of 41-50 years old, with 69% of the users above the age of 41.

Current Use and Access

The following table describes the average ranking on a scale of 1 to 10 (with 1 being not important, 10 being very important) of 17 listed weather conditions. With this group of users, dangerous weather situations were most important in their decision-making processes. As illustrated in Figure 20, blizzards, sleet or freezing rain, freezing drizzle or fog, moderate to heavy snow, and blowing snow all ranked high on the scale of importance. Additional weather that impacts general travel, such as flooding, bridge and road frost, tornadoes and severe thunderstorms ranked next in importance.

With the available weather information available today, this user group finds National Weather Service warnings to be most important at 83.3%. Next in order of usefulness was a tie between site-specific information and map-based regional weather information at 75%. Weather radar and camera images were also very useful, at 68.8% and 62.5% respectively. Almost every resource listed on this survey was found at least somewhat useful, except for marine information that 51.6% indicated it was not useful.

Currently the most effective methods of accessing this information was the Internet at 84.4% and television/radios at 51.6%. Telephone and email were noted as moderately effective at 34.4% and 35.5% respectively, with faxes (46.9%) and pagers (40.6%) only being marginally effective.

The research community surveyed stated that their most used ESS data was camera imagery (47.6%). Observed weather data and observed pavement data from ESS were next, ranking at 28.6% and 14.3% respectively. Three of twenty-one respondents (14.3%) replied that they used all reference data.

Parameters from available ESS used by this user group to support research activities varied greatly. Those used occasionally to routinely were road conditions at 79%, camera images and snow depth both at 68%, precipitation type at 67%, and visibility at 61%. The surveyed researchers seldom or never used the rest of the available data from ESS. The greatest concern was data arriving too late, at 33.3%. However, 38.6% of this group found no concern at all with data arrival timing. They were slightly concerned with a lack in quality control at 50%, but only 22% were moderately to very concerned with this issue. Only 16 of 32 respondents answered the question regarding the type of research for which road weather data was used. Sixty-three percent of these individuals responded with highway safety as their research area.

Three users all commented that they do not use this in their research, only for travel for job related purposes or staff travel.

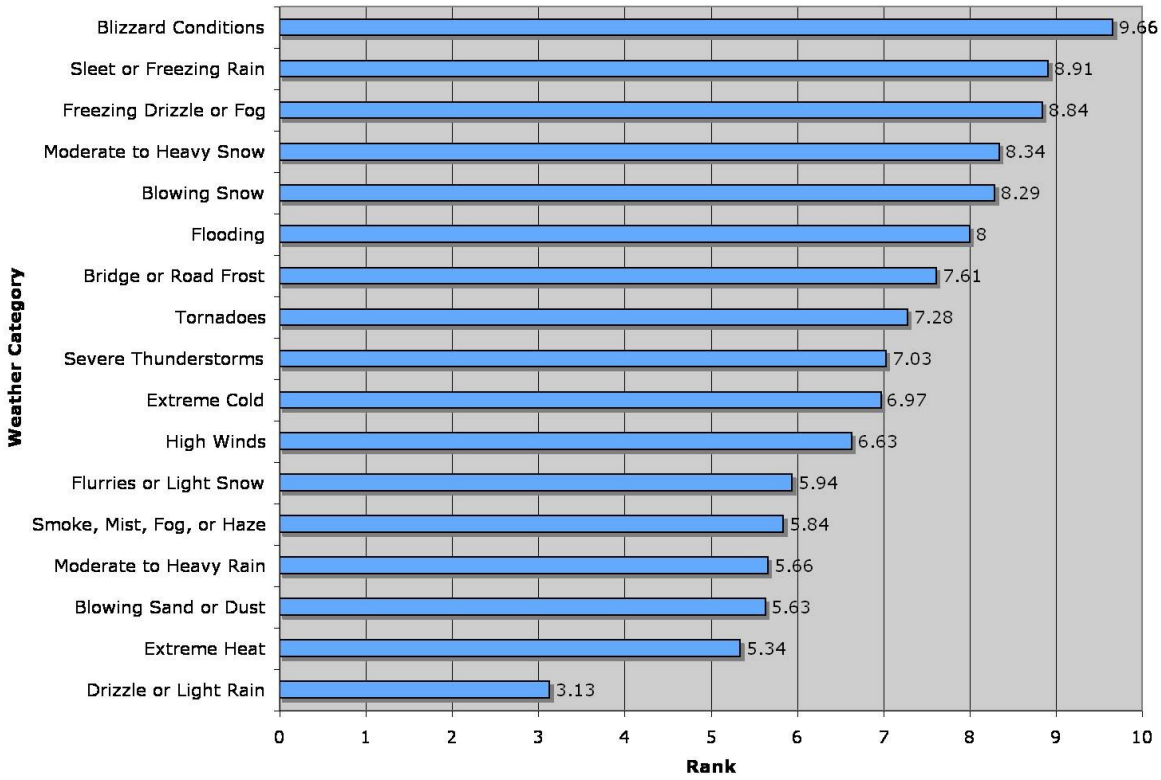

Figure 20. Research Community weather concerns.

Future Expectations

As technology advances in the future, this user group responded at 66.7% preferring to use in-vehicle display systems for road weather information. Using AM/FM radio was their next preference at 50%. However, this would be useful for using road weather information for travel, not for research. A few responded that the Internet was still a necessary way to get valuable information, and should have been included in this question. Another respondent mentioned that cell phone coverage was still very unreliable in his state, even along portions of an interstate, and cannot be depended upon to receive information. Finally, one individual mentioned tying weather into a commercial service such as OnStar, so that it could warn of dangerous weather conditions in the wintertime would be useful. Once again, these were largely related to travel, and not to a research environment.

Conclusions

Due to some comments made and responses to the survey, the research community may have made more of a distinction of which conditions impacted travel rather than for their research. The response ranking NWS watches and warning as the first choice of weather data can be associated with the respondents' personal use of data rather than research emphasis.

Surprisingly, the research community does not have any major concerns with ESS data. However, there were a number of the researcher survey respondents who expressed concerns with timeliness and accuracy and did not really change this view with the questions focused on the future and the improved quality checking and reliability of the information. In addition, it was not surprising to see no great improvements in use with the suggestion of text or video messaging of warnings and data was this is not the location these users would want to acquire the data. However, comments were made that related to safe travel in reference to wireless access being limited in various areas of some of the North/West Passage states.

Summary of User Needs

The previous section presented individual assessments of each North/West Passage Clarus stakeholder group. Given the geographic location of the eight North/West Passage states along the northern tier of the United States, the designation of winter weather hazards as the dominant weather interest is expected (Figure 21). While the majority of survey respondents expressed travel, i.e. general public and commercial vehicle operators, as their principal interest area, the responses of this group were strikingly similar in many regards to the responses from other stakeholder groups. This was reflected in the interest of all groups to promote a safe travel capability and to maximize the movement along the highway system.

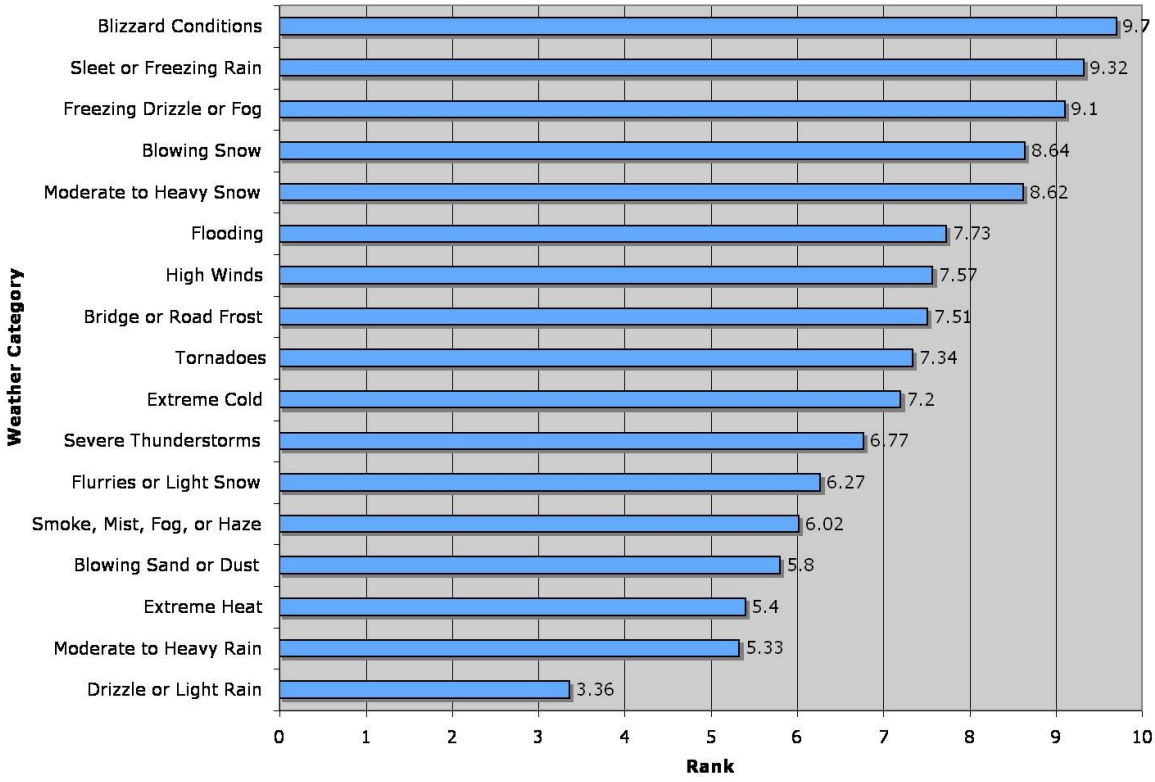

Figure 21. Overall averages for all User Groups weather concerns

User needs found during this analysis represented a composite of findings from a synthesis of the web-based surveys of stakeholders, composites of the site interviews conducted within each North/West

Passage state, consideration of existing state and regional ITS architectures, and the goals and ideals that served as the foundation for the North/West Passage Transportion Pooled Fund project. Generally, the North/West Passage states and the surveyed stakeholders agreed that having improved site-specific and broader road network weather and road conditions was a need. Whether this information was to be used by state agencies for improved implemtation of advisory, control, and treatment road weather management strategies or by travelers for better-informed travel decision-making, a synergy existed in the user needs. Some of the specific findings from the user needs analysis included:

- The World Wide Web was the primary information access method by agency and non-agency stakeholders for in-state and cross-state information related to road conditions and weather.
- Information alerts to changing conditions, particularly road conditions, would be an acceptable method for providing support to travel planning and decision making
- Travelers when making winter travel plans spanning long distances seek multi-state information. This information included road condition, imposed controls and observed/forecasted weather
- The demand for multi-state road condition and weather information by state agencies is not as high of a demand as it is for travelers although state agency interest is maximized along borders.
- If available, forecasted road conditions would be of interest to the traveling public
- The lack of timely, reliable, accurate observations (particularly from ESS) is a significant stigma attached to current road weather observations
- The lack of confidence in weather and road condition forecasts by maintenance personnel is a hinderance in decision making
- Travelers (general public and CVO) interest exists in improved travel go/no go decision support
- The awareness of 511 as a primary source of travel information remains below other less travel focused information sources. Improved decision support content and better information reliability would significantly increase the utilization and awareness of 511.
- In-vehicle information delivery systems are expected to be a major technology advancement in travel decision support
- Web map displays of road weather / road condition information are stove-piped to individual states and do not do provide adequate integration in support of regional traveler support
- Multi-state weather / road condition web portals would greatly enhance the exchange of information across states and support stakeholder use.
- Assessment of weather service provider response suggest that Clarus quality checked data is of limited benefit and that existing quality checking methods by the weather service providers will continue to take precedence.
- The availability of ESS data is a concern to personnel in state transportation agencies both from the spatial and temporal availability of the data.
- Site-specific weather information along the roadway is of significant interest to both the operators and users of the highway system and the reliance on this data is limited only by the availability, accessibility, and quality of the information.

User Need 1: Interstate Advisory and Control Strategy Communication Coordination

Situations were cited by state department of transportation operations personnel where closing a road in a neighboring state results in significant impacts on the transportation actions in their state e.g. long lines of vehicles waiting for roads to re-open or travelers needing lodging. Having information in advance or at the time of imposition of these controls would provide an effective means of both informing the traveling public of travel delays or need for detours as well as improve the maintenance coordination across state borders.

User Need 2: Implementation of a Fine-Resolution, Multi-State Road Network Road Condition Reporting

System
Complementing the need for advisory and control actions in adjacent states is the need for more reliable and spatially specific road condition information. This is a challenge for the present ESS to detect and actual road conditions are more often observed during route patrols. Having better information is not just limited to the observed conditions, but also to forecast conditions. The latter becomes crucial in planning activities for both state DOTs and travels. The availability of this road condition information can be communicated.

User Need 3: Implementation of a Fine-Resolution, Multi-State Road Network Road Condition/Road Weather Forecast System
For travelers planning to traverse distances beyond one state or even an entire Interstate corridor, there is a need to have reliable information on future road and weather conditions for planning purposes. The present dependance is upon reported road conditions and relating these to anticipated future weather conditions. For CVO long-haul traffic, where dispatch decisions on one end of a corridor must take into consideration what will be transpiring as the vehicle approaches its destination, much is left to chance during periods of inclement weather. For all travelers, the capability of making go/no go decisions during winter is left to chance and reduces traveler confidence on safe travel. This calls for greater synthesis of weather forecast information with anticipated (forecast) road conditions.

User Need 4: Integration of 511 Systems to Provide Corridor-Wide Exchange of Information
Present 511 systems have limited capabilities to access information across borders and are limited to the exchange of information with adjancent states. Providing mechanisms to permit the data warehousing of traveler information, including current /forecast road conditions and weather conditions would provide a framework enhancing traveler decision support along full highway corridors spanning multiple states.

User Need 5: Development of an Automated Traveler Alert and Notification System
The availability of wireless and cellular messaging provides the opportunity for proactive notification of changing road and weather conditions to support traveler decision-making activities. Such notifications can be incorporated into a corridor-wide road condition / weather forecasting system. A web-based user subscription to the alert system would permit users to configure the details of information included in the notifications.

User Need 6: Generation of a North/West Passage Corridor-Wide Weather Information Portal
Each of the North/West Passage states provides access to ESS data for their respective states. However, the general North/West Passage stakeholder community of users must visit individual state web resources to view weather information outside of their states. Further, most of the states do not provide additional weather observations from other observation platforms that would complement the ESS observations for a state. The generation of a unified web-based resource for depicting the multitude of weather observations, both in situ and remotely sensed, across the eight North/West Passage states would provide a useful resource for the broader stakeholder community.

User Need 7: Expansion of the Spatial and Temporal Collection of Quality Road Weather Observations
The real and perceived low quality issues that limit the inclusion of these data in weather service provider product generation activities have blunted the usefulness of ESS data. However, the limited spatial coverage of these observations in areas where microscale forecasting is an issue and the low frequency of most ESS observations is also a significant hindrance to data usage. The states owners of the ESS networks, or RWIS, should develop a strategic plan for the expansion of the ESS network and the methods to ensure that quality, and timeliness of the data are guaranteed.

User Need 8: Incorporation of ESS Camera Images within the Clarus System

The use of video cameras on ESS and other transportation related platforms has expanded greatly in recent years. The availability of these images via web pages has prompted a significant use of this information by the operators and users of the highway system. However, the lack of availability of these data as part of the Clarus System results in a major challenge to collect these images for the purpose of display or incorporation into other road weather service products that span a multi-state region. Incorporation of these images into Clarus would provide a data warehouse for these images and permit a more comprehensive utilization in road weather applications.

Appendix C – User Case Scenario Diagrams

The use case scenario diagrams that follow are associated with UML packages incorporated in the use case scenario diagrams in Section 6. These diagrams provide the actors and use cases associated with aspects of the North/West Passage Use Case Scenarios that are repetitive among the four use case scenarios central to the Concept of Operations design. Figure 22 represents the collection of ESS data at the state agency and the accumulation of these data prior to transfer to the *Clarus* System. The data exchange between the State ESS Network and the Clarus System is bi-directional in that quality-checking data are returned to the State ESS Network. These data are used to perform maintenance and calibration activities and provide a measure of the integrity of the state's ESS network. The State DOT Operator represents the transfer of ESS data directly to a state transportation agency. Primarily, the ESS data will already be available in-house for the state where the data are collected. However, some ESS data such as camera images are not presently part of the *Clarus* System although being of high demand by state transportation agency personnel. The presence of the State DOT Operator provides the association with the corresponding State DOT package where ESS camera images are transferred.

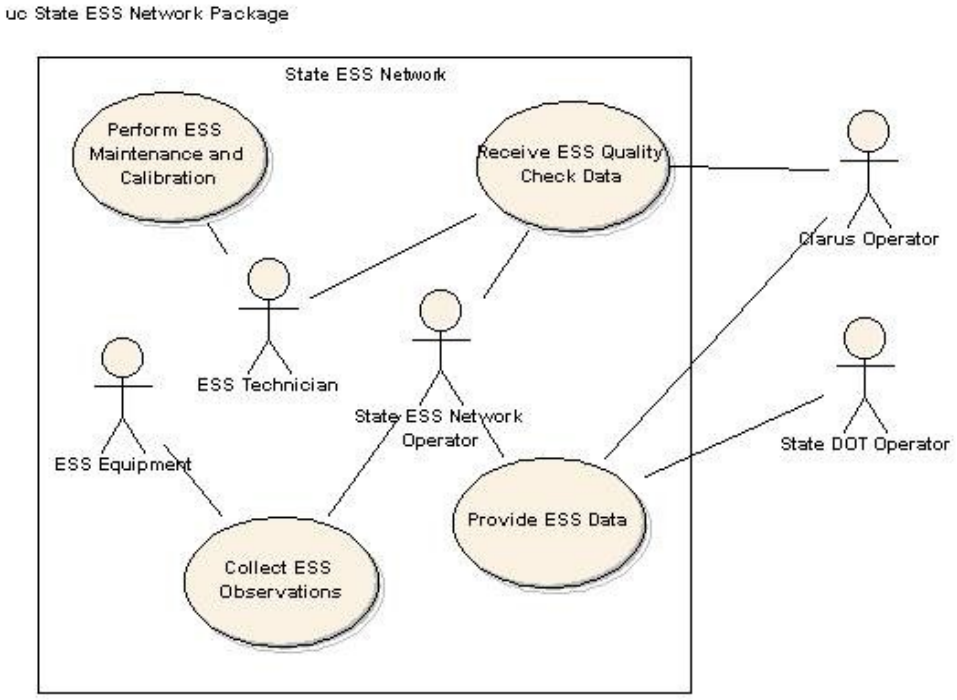

Figure 22. Use Case Diagram based upon the functionality defined for the State ESS Network.

Figure 23 provides a depiction of who the *Clarus* System appears to the North/West Passage Concept of Operations. The actors associated with this system include the operator of the State ESS Network and the weather services entities engaged in provision of weather and surface transportation weather services to state transportation agencies. This latter provision is central to the basic concept that the weather service provider community is the fundamental user of *Clarus* data.

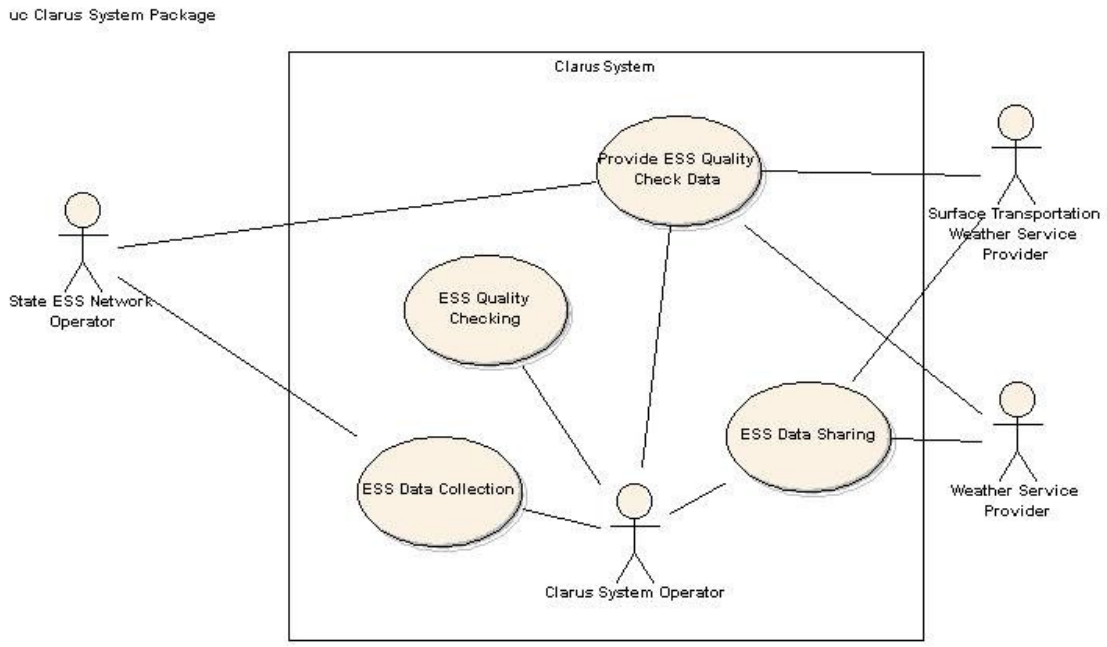

Figure 23. Use Case Diagram based upon the functionality defined for the Clarus System.

Figure 24 provides the use case scenario for the weather services incorporated within the Concept of Operations. The specific processes involved in weather analysis and forecasting services will vary greatly by the entity and organization performing the tasks. This use case scenario includes the weather service provider and surface transportation weather service provider actors. While both of these entities may be public sector, the majority of the surface transportation weather service providers will typically be from the private sector. The distinguishing features between these two providers are noted best in the use cases performed. While the surface transportation weather service provider often performs the same weather analysis and forecasting tasks as the weather service provider, the former provides tailored weather analyses and forecasts to the roadway environment including the analysis and prediction of pavement temperature and conditions. This latter activity is the single most defining difference between these to entities.

The data inputs used by the weather services include the *Clarus* data and other available weather data. These data include remotely sensed data of the atmosphere e.g., weather radar and satellite, and *in situ* observations made at the surface and aloft. The volume of data from the external data sources is vast when compared with the ESS data. However, these generally available external data sources often provide little insight into the conditions existing in the roadway environment. Thus, the value of the ESS data is high and become central to the weather analysis and forecasting process. Associates from the weather services use case scenario extend to all the Concept of Operations use case scenarios as well as to the State DOT package. The latter use weather and surface transportation weather data to perform decision making for other use cases of interest to agency operations.

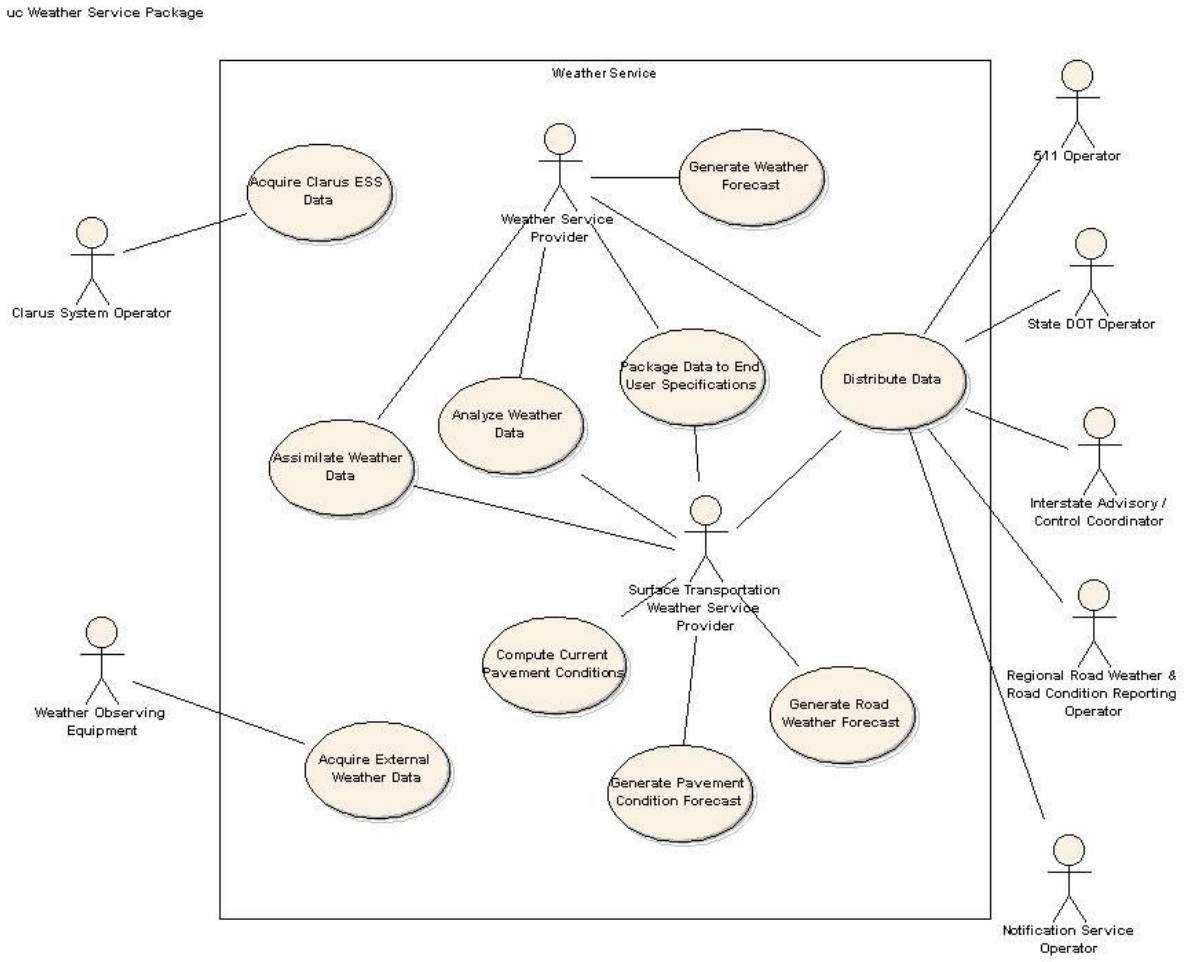

Figure 24. The Use Case Diagram based upon the functionality defined for the Weather Services package.

Figure 25 depicts the use case scenario for the functions associated with the State DOT package. The primary actors in inside the State DOT package are restricted to those involved with decision making associated with advisory, control, and treatment activities. An additional external actor, State Patrol, is added to this package given the typical involved of public safety agencies in determining advisory and control actions and their involvement in provide observations of road conditions. The function provided in the use case scenario involves the generation and reception of data and information from various other use cases. These include associations with weather services as well as with traveler information. The feedback received from regional activities is used to provide planning and coordination activities associated primarily with winter maintenance.

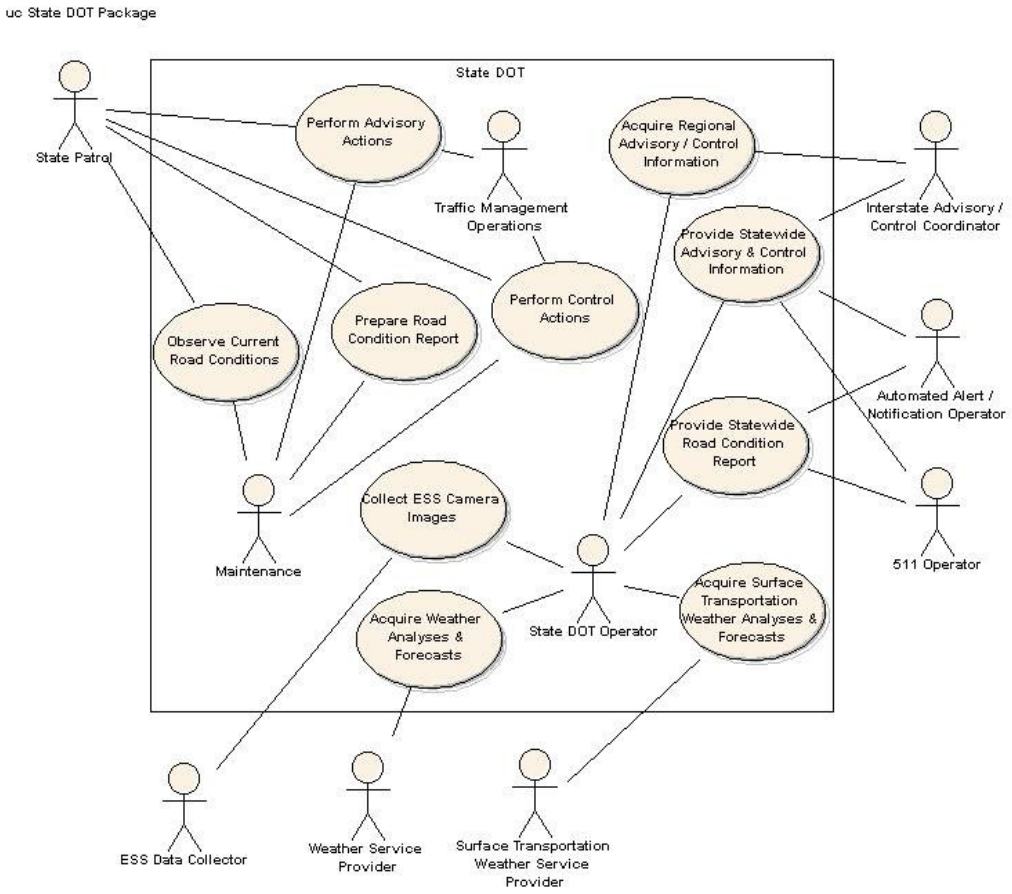

Figure 25. The Use Case Diagram based upon the functionality defined for the State DOT package.

Appendix D – North/West Passage *Clarus* Regional Demonstration Use Case Actor Descriptions

511 System Operator

The Integrated 511 System Operator actor collects, processes, stores, and disseminates enhanced road weather content information to system operators and the traveling public. Information provided includes weather information, basic advisories, traffic and road/route conditions, transit schedule information, yellow pages information, ride matching information, and parking information. The 511 System Operator can utilize both basic one-way (broadcast) and personalized two-way information communication. The entity provides the capability for an informational infrastructure to connect providers and consumers across the Interstate and National Highway System North/West Passage region.

Member of Use Case Scenarios:

- Enhanced Road Weather Content for 511 Information Systems
- Regional Road Weather and Road Condition Reporting System

Clarus *System Operator*

The *Clarus* System Operator actor manages the collection, integration and dissemination of all data within the *Clarus* System.

Member of Use Case Scenarios:

- Enhanced Road Weather Content for 511 Information Systems
- Interstate Advisory/Control Coordination
- Regional Road Weather and Road Condition Reporting System
- Regional Alert Notification System

Commercial Vehicle Operations

The Commercial Vehicle Operations actor provides the capability for commercial drivers and fleet managers to receive weather information and to monitor the safety and security of their commercial vehicle drivers and fleet.

Member of Use Case Scenarios:

- Enhanced Road Weather Content for 511 Information Systems
- Interstate Advisory/Control Coordination
- Regional Alert Notification System

ESS Data Collector

The ESS Data Collector actor collects ESS measurement data from the ESS Equipment actor.

Member of Use Case Scenarios:

- Enhanced Road Weather Content for 511 Information Systems
- Interstate Advisory/Control Coordination
- Regional Road Weather and Road Condition Reporting System
- Regional Alert Notification System

ESS Equipment

The ESS Equipment actor represents the Environmental Sensor Stations collecting environmental data.

Member of Use Case Scenarios:

- Enhanced Road Weather Content for 511 Information Systems

- Interstate Advisory/Control Coordination
- Regional Road Weather and Road Condition Reporting System
- Regional Alert Notification System

Interstate Advisory/Control Coordination

The Interstate Advisory/Control Coordination actor performs the communications and coordination of the collection, compilation, and distribution of road weather management advisory and control strategies.
Member of Use Case Scenarios:

- Interstate Advisory/Control Coordination

Maintenance Operator

The Maintenance Operator actor monitors and manages roadway infrastructure winter maintenance activities. Representing both public agencies and private contractors that provide these functions, this actor manages fleets of winter maintenance, or special service vehicles (e.g., snow and ice control equipment). The actor receives a wide range of status information from these vehicles and performs vehicle dispatch, routing, and resource management for the vehicle fleets and associated equipment. This actor manages equipment at the roadside, including environmental sensors and automated systems that monitor and mitigate adverse road and surface weather conditions. This actor manages the repair and maintenance of both non-ITS and ITS equipment including the traffic controllers, detectors, dynamic message signs, signals, and other equipment associated with the roadway infrastructure. Additional interfaces to weather information providers (the weather service and surface transportation weather service providers) provide current and forecast weather information that can be fused with other data sources and used to support advanced decision support systems that increase the efficiency and effectiveness of winter maintenance operations.
Member of Use Case Scenarios:

- Enhanced Road Weather Content for 511 Information Systems
- Interstate Advisory/Control Coordination
- Regional Road Weather and Road Condition Reporting System
- Regional Alert Notification System

Media

The Media actor represents a major consumer of road weather information for the support of a broad array of stakeholders ranging from travelers to the public.
Member of Use Case Scenarios:

- Interstate Advisory/Control Coordination
- Regional Road Weather and Road Condition Reporting System

Notification Service Operator

The Notification Service Operator actor provides oversight to the functional activities of the automated alert notification service function.
Member of Use Case Scenarios:

- Regional Alert Notification System

Recreation Facility Operators

The Recreation actor uses the facilities of the outdoors, such as those provided by state or national parks. This actor uses data from traveler information systems to enhance its safety in a vulnerable outdoor environment.

Member of Use Case Scenarios:

- Interstate Advisory/Control Coordination

Regional Road Weather and Road Condition Reporting Operator

The Regional Road Weather and Road Condition Reporting Operator actor represents the coordination and communications to facilitate a regional generation and utilization of a regional reporting system.

Member of Use Case Scenarios:

- Regional Road Weather and Road Condition Reporting System

State Patrol

The State Patrol actor is responsible for overseeing and enforcing traffic safety compliance on roads and highways. This actor will often be the first responder to incidents that may be affected by significant weather impacts. This actor will monitor and report damage to or poor conditions of roads.

Member of Use Case Scenarios:

- Enhanced Road Weather Content for 511 Information Systems
- Interstate Advisory/Control Coordination
- Regional Road Weather and Road Condition Reporting System

State Road Condition Reporting System Operator

The State Road Condition Reporting System Operator actor manages the coordination and communication of road condition information collection and compilation. The actor is also designated as the coordinating agent with the Regional Road Weather and Condition Reporting Function to ensure that the state's road condition information is made available to the regional system. The actor has oversight for reception of regional road weather and condition reports for use within the state's operations.

Member of Use Case Scenarios:

- Regional Road Weather and Road Condition Reporting System

Surface Transportation Weather Service Provider

The Surface Transportation Weather Service Provider actor receives data from the *Clarus* System and provides value-added weather and surface transportation data integration and interpretation to the Weather Information User Community.

Member of Use Case Scenarios:

- Enhanced Road Weather Content for 511 Information Systems
- Interstate Advisory/Control Coordination
- Regional Road Weather and Road Condition Reporting System
- Regional Alert Notification Syste

TOC / TMC Operator

The TOC/TMC Operator actor monitors and controls the road network and traffic. It represents centers that manage a broad range of transportation facilities including freeway systems, rural and suburban highway systems, and urban and suburban traffic control systems. This actor monitors and manages

traffic flow and monitors the condition of the roadway, surrounding environmental conditions, and field equipment status.

Member of Use Case Scenarios:

- Enhanced Road Weather Content for 511 Information Systems
- Interstate Advisory/Control Coordination
- Regional Road Weather and Road Condition Reporting System

The Traveler Support Services

The Traveler Support Services actor provides a bridge between the various transportation support systems that assist travelers, both general travelers and commercial vehicle operators through the provision of lodging and traveler services. The Traveler Support Services actor often delivers traveler information to customers and often provides assistance during inclement weather and driving conditions.

Member of Use Case Scenarios:

- Enhanced Road Weather Content for 511 Information Systems

Travelers

The Travelers actor collects, processes, stores, and disseminates transportation information to system operators and the traveling public. The actor can play several different roles in an integrated ITS. In one role, the Traveler actor provides a general data warehousing function, collecting information from transportation system operators and redistributing this information to other system operators in the region and other ISPs. In this information redistribution role, the Traveler actor provides a bridge between the various transportation systems that produce the information and the other ISPs and their subscribers that use the information. In a second role, a Traveler actor is focused on delivery of traveler information to subscribers and the public at large. Information provided includes basic advisories including weather, traffic and road/route conditions, transit schedule information, yellow pages information, ride matching information, and parking information. In a third role, the Traveler actor may be dedicated to, or even embedded within, the dispatch system.

Member of Use Case Scenarios:

- Enhanced Road Weather Content for 511 Information Systems
- Interstate Advisory/Control Coordination
- Regional Alert Notification System

Traveler Support Services

The Traveler Support Services actor provides a bridge between the various transportation support systems that assist travelers, both general travelers and commercial vehicle operators through the provision of lodging and traveler services. The Traveler Support Services actor often delivers traveler information to customers and often provides assistance during inclement weather and driving conditions.

Member of Use Case Scenarios:

- Interstate Advisory/Control Coordination

Weather Observing Equipment

The Weather Observing Equipment actor represents environmental sensing equipment that provides weather observation data from stations not included in the *Clarus* System.

Member of Use Case Scenarios:

- Enhanced Road Weather Content for 511 Information Systems
- Interstate Advisory/Control Coordination
- Regional Road Weather and Road Condition Reporting System

- Regional Alert Notification System

Weather Service Provider

The Weather Service Provider actor provides data to the *Clarus* System based on its weather observation equipment. The Weather Service Provider integrates, transforms and interprets general weather data including data from the *Clarus* System for dissemination to the Weather Information User Community.

Member of Use Case Scenarios:

- Enhanced Road Weather Content for 511 Information Systems
- Interstate Advisory/Control Coordination
- Regional Alert Notification System

Appendix E – North/West Passage *Clarus* Regional Demonstration Use Case Descriptions

Acquire External Weather Data

The Acquire External Weather Data use case is external to the *Clarus* System Framework. This use case is responsible for collecting the external weather data from the Weather Observing Equipment actor, which includes products and services generated by the National Oceanic and Atmospheric Administration (NOAA), Environment Canada, and various weather data service providers. These may include numerical weather depiction guidance, forecasts, and public or private environmental sensor data from sensors not directly connected to *Clarus*. The use case delivers the information to the Weather Service Provider actor and the Surface Transportation Weather Service Provider actor.

Member of Use Case Scenarios:

- Enhanced Road Weather Content for 511 Information Systems
- Interstate Advisory/Control Coordination Use Cases:
- Regional Alert and Notification System Use Cases

Collect Regional Advisory Information

The Collect Regional Advisory Information use case performs the actions associated with assimilating road weather management advisory strategies implemented by North/West Passage states. The collection of information incorporates the use of appropriate ITS and affiliated communications protocols.

Member of Use Case Scenarios:

- Interstate Advisory/Control Coordination Use Cases:

Collect Regional Control Information

The Collect Regional Control Information use case performs the actions associated with assimilating road weather management control strategies implemented by North/West Passage states. The collection of information incorporates the use of appropriate ITS and affiliated communications protocols.

Member of Use Case Scenarios:

- Interstate Advisory/Control Coordination Use Cases:

Collect Regional Forecasted Road Conditions

The Collect Forecasted Regional Road Conditions use case performs the actions to assimilate the projected future weather-related pavement conditions.

Member of Use Case Scenarios:

- Regional Road Condition Reporting System

Collect Regional Road Conditions

The Collect Regional Road Conditions use case performs the actions to acquire and store the data from statewide road conditions reporting systems supported in the North/West Passage 511 systems.

Member of Use Case Scenarios:

- Enhanced Road Weather Content for 511 Information Systems
- Regional Road Condition Reporting System

Collect Route-Specific Road Weather Conditions

The Collect Route-Specific Road Weather Conditions use case performs the actions to assimilate current and future road conditions from state agency resources including those obtained by the state agencies through the surface transportation weather services providers. This use case stores the data collected in a database providing capabilities for querying by the 511 system distribution.

Member of Use Case Scenarios:

- Enhanced Road Weather Content for 511 Information Systems

Configure Alert Notification Criteria

The Configure Alert Notification Criteria use case provides the actions associated with the setting of threshold values and geospatial locations desired in the various types of road weather elements for which an automated alert notification is available.

Member of Use Case Scenarios:

- Regional Alert and Notification System Use Cases

Distribute Advisory & Control Information

The Distribute Advisory and Control Information use case is the action to promote the utilization of regional advisory and control information by state decision makers and a range of stakeholders outside of state organizations who use the information to promote greater safety, mobility and productivity. The information is an aggregation of the advisory and control road weather management strategy information generated by the North/West Passage states. The compilation of regional advisory information is maintained in a relational database.

Member of Use Case Scenarios:

- Interstate Advisory/Control Coordination Use Cases:

Distribute Alert

The Distribute Alert use case provides the actions associated with the delivery of road weather information to an end-user subscriber. These services are provided through a subscription process where system users provide pre-configured information request profiles.

Member of Use Case Scenarios:

- Regional Alert and Notification System Use Cases

Distribute Regional Road Condition Information

The Distribute Regional Road Condition Information use case performs the dissemination of existing and predicted road and weather information to a diverse community of users dealing with transportation-related programs.

Member of Use Case Scenarios:

- Regional Road Condition Reporting System

Distribute Traveler Information

The Distribute Traveler Information use case provides the external accessibility to 511 information services. This interface is generally supported through a combination of computer telephony and web-based delivery methods.

Member of Use Case Scenarios:

- Enhanced Road Weather Content for 511 Information Systems

ESS Data Collection

The ESS Data Collection use case is part of the *Clarus* System Framework. This use case is responsible for transferring the collected ESS data from the ESS Data Collector actor to the *Clarus* System Operator.

Member of Use Case Scenarios:

- Enhanced Road Weather Content for 511 Information Systems
- Interstate Advisory/Control Coordination Use Cases:
- Regional Road Condition Reporting System
- Regional Alert and Notification System Use Cases

ESS Data Serving

The ESS Data Serving use case is part of the *Clarus* System Framework. This use case is responsible for transferring the processed ESS data, quality control flags, and pertinent metadata to the Weather Service Provider, Surface Transportation Weather Service, the state transportation decision maker actors, and potentially other interested stakeholders. The *Clarus* operator has the capability to specify critical ESS information processing priorities for the *Clarus* System.

Member of Use Case Scenarios:

- Enhanced Road Weather Content for 511 Information Systems
- Interstate Advisory/Control Coordination Use Cases:
- Regional Road Condition Reporting System
- Regional Alert and Notification System Use Cases

ESS Quality Checking

The ESS Quality Checking use case is part of the *Clarus* System Framework. This use case is responsible for checking and flagging the collected ESS data. The *Clarus* quality control process will check for observed values that exhibit out-of-tolerance limits and other data characteristics that require flagging and will set quality exception flags where necessary. The process will notify the ESS Data Collector actor of observed values that consistently report quality exception flags. The ESS Quality Checking use case will rely upon current ESS metadata provided by the ESS Data Collector actor that include configuration and operational status information.

Member of Use Case Scenarios:

- Enhanced Road Weather Content for 511 Information Systems
- Interstate Advisory/Control Coordination Use Cases:
- Regional Road Condition Reporting System
- Regional Alert and Notification System Use Cases

Generate Geospatial Representation of Road Condition Reports

The Generate Geospatial Representation of Road Condition Reports use case conducts the geospatial actions to associate road conditions to site-specific road network locations.

Member of Use Case Scenarios:

- Regional Road Condition Reporting System

Generate Statewide Road Condition Report

The Generate Statewide Road Condition Report use case prepares a summary of all incidents, construction activities and current and/or future road conditions due to changing weather conditions and

as altered by road weather management treatment strategies. The statewide nature of the system provides a systematic approach to consolidation of the above road conditions.
Member of Use Case Scenarios:

- Regional Road Condition Reporting System

Implement a Maintenance Treatment Strategy

The Implement a Maintenance Treatment Strategy use case is a process within the Maintenance Personnel actor analyzes the pavement conditions, the forecasted weather conditions, the available resources, and agency policies to perform the best treatment option. The Maintenance Operator for each agency manages this use case.
Member of Use Case Scenarios:

- Regional Road Condition Reporting System

Maintain Road Condition Database

The Maintain Road Condition Database use case performs the management activities to store all regional road condition data in a relational database following a schema that corresponds to the various data types defined in the schema.
Member of Use Case Scenarios:

- Regional Road Condition Reporting System

Monitor Alert Criteria

The Monitor Alert Criteria use case provides the actions associated with the processing of threshold mechanisms in the alert notification profile that matches the criteria corresponding to those defined by the end-user. This end-user may be an individual motorist or an individual in a transportation organization charged with making operational decisions that are road weather dependent.
Member of Use Case Scenarios:

- Regional Alert and Notification System Use Cases

Observe Current Road Conditions

The Observe Current Road Conditions use case performs the actions to acquire current road condition system information. This information includes incident, construction, and weather-related pavement conditions.
Member of Use Case Scenarios:

- Interstate Advisory/Control Coordination Use Cases:
- Regional Road Condition Reporting System

Support Regional Road Condition Reporting System

The Support Regional Road Condition Reporting System use case performs the functions supporting the querying and updating of the regional road condition database by state decision makers and the stakeholders who assimilate the information into their information dissemination efforts i.e. 511.
Member of Use Case Scenarios:

- Enhanced Road Weather Content for 511 Information Systems

Perform Advisory Actions

The Perform Advisory Actions use case conducts the actions necessary to determine and apply road weather management advisory strategies.

Member of Use Case Scenarios:

- Interstate Advisory/Control Coordination Use Cases:

Perform Control Actions

The Perform Control Actions use case conducts the actions necessary to determine and apply road weather management advisory strategies.

Member of Use Case Scenarios:

- Interstate Advisory/Control Coordination Use Cases:

Provide ESS Measurement

The Provide ESS Measurement use case covers the process wherein the ESS Equipment actor facilitates the observation of road and weather conditions from environmental sensor stations.

Member of Use Case Scenarios:

- Enhanced Road Weather Content for 511 Information Systems
- Interstate Advisory/Control Coordination Use Cases:
- Regional Alert and Notification System Use Cases

Provide Surface Transportation Weather Analysis & Forecast

The Provide Surface Transportation Weather Analysis and Forecast use case covers the process wherein the Surface Transportation Weather Service Provider actor integrates weather information from the Acquire External Weather Data, ESS Data Serving, and Regional Road Condition Reporting System use cases, generates analyses and forecasts of both weather and pavement conditions, and disseminates the information to the Weather Information Consumer Community. The Weather Information Consumer Community actors include state decision makers who incorporate the resulting weather information to support their decision-making processes.

Member of Use Case Scenarios:

- Enhanced Road Weather Content for 511 Information Systems
- Interstate Advisory/Control Coordination Use Cases:
- Regional Alert and Notification System Use Cases

Provide Traveler Information

The Provide Traveler Information use case conducts the needed actions to distribute traveler information to a wide array of stakeholders. The primary instantiation of this action is using 511 ATIS methods and the use of the World Wide Web. This use case includes state decision makers who incorporate the resulting weather information to support their decision-making processes.

Member of Use Case Scenarios:

- Enhanced Road Weather Content for 511 Information Systems
- Interstate Advisory/Control Coordination Use Cases:

Provide Weather Analysis & Forecast

The Provide Weather Analysis and Forecast use case covers the process wherein the Weather Service Provider actor integrates weather information from the Acquire External Weather Data and ESS Data Serving use cases, generates analyses and forecasts of weather and disseminates the information to the Weather Information Consumer Community. The Weather Information Consumer Community actors include state decision makers who incorporate the resulting weather information to support their decision-making processes.

Member of Use Case Scenarios:

- Enhanced Road Weather Content for 511 Information Systems
- Interstate Advisory/Control Coordination Use Cases:
- Regional Alert and Notification System Use Cases

Trigger Alert

The Trigger Alert use case generates an action leading to a distribution of an automated alert when processing of the trigger mechanisms in the alert notification profile matches the criteria as determined after a scan of the desired thresholds exceeded in the system's road weather database. This service has a dependency in a multi-jurisdictional implementation where the cross-jurisdictional data are acquired from the database generated from contributions from all North/West Passage states.

Member of Use Case Scenarios:

- Regional Alert and Notification System Use Cases

Utilize Maintenance Decision Support System

The Utilize Maintenance Decision Support System use case incorporates a decision-making process designed to utilize current and projected road, weather conditions, resource utilization plans to effect the desired level of service associated with winter maintenance activities. The maintenance decision support system is referred to in general terms as defined and advocated by the American Association for State Highway Transportation Officials (AASHTO) Technology Implementation Group (TIG).

Member of Use Case Scenarios:

- Regional Road Condition Reporting System