UNIVERSITY OF UND NORTH DAKOTA

Surface Transportation Weather Research Center

FINAL REPORT

OF THE

OPERATION AND DEMONSTRATION TEST

OF

SHORT-RANGE WEATHER FORECASTING DECISION SUPPORT

WITHIN AN

ADVANCED TRANSPORTATION WEATHER INFORMATION SYSTEM

(#SAFE)

Prepared For:

U.S. Department of Transportation

Federal Highway Administration

April 2006

TABLE OF CONTENTS

Executive Summary

Initially proposed in early 1995 by the University of North Dakota Regional Weather Information Center, the Advanced Transportation Weather Information System (ATWIS) was designed to provide en-route weather forecasts and road condition information to the traveling public. While a number of activities were underway by other groups to operationally test and evaluate metro or urban traveler information systems in the 75 major transportation markets, ATWIS embarked to determine whether it was possible to provide a national standard for statewide or multi-state systems that addressed the long distance and commuter travelers' needs across a wide variety of industries.

ATWIS was the first system to develop, test, and produce an operational rural system for travel across vast open spaces, where road conditions and weather information are essential to economic and personal safety. ATWIS capitalized on the existing wireless telecommunication infrastructure while designing a system that can easily expand and adapt to the rapidly changing telecommunications industry. In accomplishing its goals, ATWIS has utilized Intelligent Transportation Systems Integration to merge technologies from meteorology, computer science, wireless telecommunication, road weather monitoring and forecasting, and transportation together into a single decision support system that can respond, adapt, and disseminate information on short notice, within a recurring cycle. ATWIS has the ability to quickly adjust to changes in information standards, formats, and protocols as this industry matures.

The Advanced Transportation Weather Information System (ATWIS) was a pioneering endeavor that opened the technological doorway for the present day advances in traveler safety and mobility. The present national 511 system that continues to expand across the nation owes its very beginning in rural areas to ATWIS and the #SAFE technologies that resulted. The ATWIS research was the first major sustained road weather research to occur on a university campus, and the benefits of the data assimilation and mesoscale weather prediction methodologies that it introduced into road weather forecasting systems has revolutionized the present practice of surface transportation weather services.

Beyond being an innovative concept for en-route travelers, ATWIS raised the level of awareness within state departments of transportation of available surface transportation weather resources available. Following a Congressional mandate to complete a successful technology transfer into a sustainable operational system, ATWIS was able to complete this task through a successful public-private partnership. This partnership resulted in a dramatic alteration of the capabilities found within the private sector and raised the level of expectation from the surface transportation weather services community.

The leadership for the success of the program can be attributed to the role of the ATWIS Steering Committee. With a membership from federal, state, and academic communities, the Steering Committee provided the insight and leadership from both the transportation and meteorological communities to forge a bold path to follow. This cross pollination between the transportation and weather communities has resulted in new research initiatives that have built upon the results of ATWIS and #SAFE. The end result of this is the birth of a new meteorological sub-discipline, the surface transportation meteorologist that will continue the progress that ATWIS has just started. In summary, the amount of knowledge gained and the new territory opened from ATWIS has been a monumental and unprecedented accomplishment in the road weather community.

I. Introduction

The purpose of the Advanced Transportation Weather Information System (ATWIS) was to provide en-route weather forecasts and road condition information to the traveling public across North Dakota and South Dakota. The ATWIS began development on June 30, 1995 at the University of North Dakota's Regional Weather Information Center (RWIC). While a number of activities were underway by other groups to operationally test and evaluate metro or urban traveler information systems in the 75 major transportation markets, ATWIS embarked to determine whether it was possible to provide a national standard for statewide or multi-state systems that addressed the long distance and commuter travelers' needs across a wide variety of industries.

During the early years of ATWIS, efforts were initiated to develop and demonstrate the utility of an en-route traveler information system. The goal was to provide operational decision support information to vehicle operators in a manner that would enhance their decision making capabilities relating to efficient and safe operation of motor vehicles along America's highways. A number of key features of this system were based on the following rules established early in program development:

a) provide easily understood information in a short concise format;
b) information will be real-time or near real-time to ensure its value to the traveler;
c) route specific weather information will be provided to detail conditions to the traveler for enhanced expectations during travel;
d) development of cost efficient methods for the collection, integration, and dissemination of information for both operations and travelers; and,
e) develop a business model to export the research benefits for both economic development and traveler safety.

ATWIS was the first system to develop, test, and produce an operational rural system for travel across vast open spaces, where road conditions and weather information are essential to economic and personal safety. ATWIS capitalized on the existing wireless telecommunication infrastructure while designing a system that can easily expand and adapt to the rapidly changing telecommunications industry. ATWIS has merged technologies from meteorology, computer science, wireless telecommunication, road weather monitoring and forecasting, and transportation together into a single decision support system that can respond, adapt, and disseminate information on short notice, within a recurring cycle. ATWIS has the ability to quickly adjust to changes in information standards, formats, and protocols as this industry matures.

The work under this Federal Highway Administration (FHWA) funded activity can be credited with the birth of an industry, with branches that have changed the expectations of associated industries and created a valuable cost effective tool for other unrelated industries. While a number of traveler information systems in urban areas were struggling to reach cost effective mass, ATWIS research through its cost efficient approach to operations brought the traveler information industry to the national forefront, designed and retooled the road weather industry, and helped to merge these new applications with a number of individual applications into what is known today as the Surface Transportation Weather Industry. This new industry is now widely recognized as containing applications and future development opportunities that are far-reaching across all transportation industries and is no longer limited to public travel.

This final report includes the development efforts undertaken and the results of these efforts. Both internal and external evaluations were conducted based on the original and later modified goals and objectives of this operational test. The final and true evaluation of the system resided in the continuation of the system through commercialization of the technology in a staged approach, providing the opportunity for further growth and development of both the system and market.

The goal of this project is to provide an evaluation and demonstration of how current technologies in mesoscale meteorological analysis and forecasting can be effectively used to produce precise spatial and temporal weather information that can be integrated into an advanced traveler information system (ATIS) for safer and more efficient operations. Upon achieving these goals, it is the desire of the project to establish a long-term, self-sustaining program to continue to provide advanced transportation weather information to the traveling public and the transportation infrastructure in which it exists.

II. The Advanced Transportation Weather Information System (ATWIS)

The final report that follows will review the problem statement, research activities, operational activities, and commercialization approach applied to the project that generated a new industry. Additionally, the ATWIS steering committee required both external and internal evaluations of key measures during the operational test. These evaluations were designed to measure the user acceptance and use of the traveler information system for decision-making. Later modified objectives included the use of the weather-related data for transportation maintenance operations. These results will be included.

II.1. Background – The Rural Transportation Problem

Weather and transportation in vast rural areas can be deadly. Over 17 percent of all fatal crashes occur during severe weather. Of these, 60 percent happen in rural areas (most on non-interstate highways). While the ATWIS Steering Committee comprised of North Dakota Department of Transportation, South Dakota Department of Transportation, and the University of North Dakota's Regional Weather Information Center recognized this problem in the late 1980s, research didn't begin until 1995. Once ATWIS was operational and providing data that supported the value and interest of the public and transportation community in such a system, the Federal Highway Administration formed a weather team in 1997 to coordinate efforts across the nation addressing a weather system for travelers as well as operators.

While a number of stand-alone systems for dynamic route guidance had been developed, marketed, and designed to provide roadway information in an urban setting, no attention had been given to the rural highway setting. The information needs of the rural traveler, both commercial and general transportation, varied according to the following situations: unfamiliar locations, advisory notices, en-route service location, and current road and weather conditions.

While these weather observations (current weather conditions) provided additional value to the understanding of current road conditions for a given travel corridor, the value of weather information to travelers was greatest when it was provided as a forecasted condition for a later segment of the travel path of the current travel plan.

II.2. Using ITS to provide solutions

While a fully established Intelligent Transportation System (ITS) architecture was not available at the start of the project, ATWIS later followed this ITS architecture designed for the future of ITS across America. ATWIS focuses on ITS market packages designed specifically for the applications hosted within ATWIS to bring the architecture to life within the project. The first focus was the traveler, the primary user of the ATWIS technology, with a goal of creating a more efficient and safer transportation system. The following quote best expresses the focus of this project for travelers and highway maintainers.

"ITS can't change the weather, but it can change the way we think about the weather. Forecasting at higher resolutions and predicting road surface conditions means that we can better understand how weather will affect the roadway. On top of this, improved decision support system and expanded information dissemination to the full range of surface transportation users and operators means that we can ultimately save lives, money, and time" (Paul Pisano, FHWA Weather Team).

II.3. Definition of the ATWIS Initiative

II.3.1. Goals

The goal of this project is to provide an evaluation and demonstration of how current technologies in mesoscale meteorological analysis and forecasting can be effectively used to produce precise spatial and temporal weather information that can be integrated into an advanced traveler information system (ATIS) for safer and more efficient operations. Upon achieving these goals, it is the desire of the project to establish a long-term self-sustaining program to continue to provide advanced transportation weather information to the traveling public and the transportation infrastructure in which it exists.

II.3.2. Objectives

To accomplish this goal, it was imperative that a close partnership among the federal, state, and private sectors be maintained. Within the federal sector, it was important to draw upon the expertise of the Federal Highway Administration for guidance and vision for the development of transportation systems within the nation. The regional focus and application of this project required state collaboration. To effectively integrate weather information into the highway systems, the Department of Transportation in each state made major commitments of support to the goals of this project and committed resources to the execution of the research plan.

Since this project was designed to become a self-sustaining operational component of an intelligent transportation system, the activities performed were expected to yield economic benefit to transportation. This was expected to facilitate privatization efforts of ATWIS, which would sustain the operational components of the system. Therefore, it was important to develop partnerships with private sector firms interested in pursuing long-term economic gains from this program. The three specific objectives of ATWIS were, and continue to be:

- Ongoing development/integration of site specific nowcasting/forecasting weather information into a decision support software environment to support analysis and interpretation of traveler information needs;
- Develop/implement effective information distribution procedures to the traveler; and,
- Estimate the marketability and user acceptance of the provided weather information leading to the transition in commercialization.

After the start of the research phase of ATWIS, the steering committee expanded the number of objectives to four to include:

- Demonstrate the feasibility of providing weather forecasting specifically for winter maintenance operations.

II.3.3. Program Administration

The administrative structure of this project is given in Figure 1. The North Dakota Department of Transportation (NDDOT), under the supervision of the Federal Highway Administration (FHWA), administered the project. Personnel representing the South Dakota Department of Transportation (SDDOT) and the University of North Dakota (UND), together with the NDDOT, served as the Steering Committee for the project with coordination from the FHWA. Administrative points-of-contact for the respective Steering Committee members included FHWA Region 8 office (until reorganization), North Dakota Field Office of the FHWA, South Dakota Field Office of the FHWA, NDDOT, SDDOT, and the Dean of the John D. Odegard

School of Aerospace Sciences at UND, and the Director of the UND Regional Weather Information Center (RWIC).

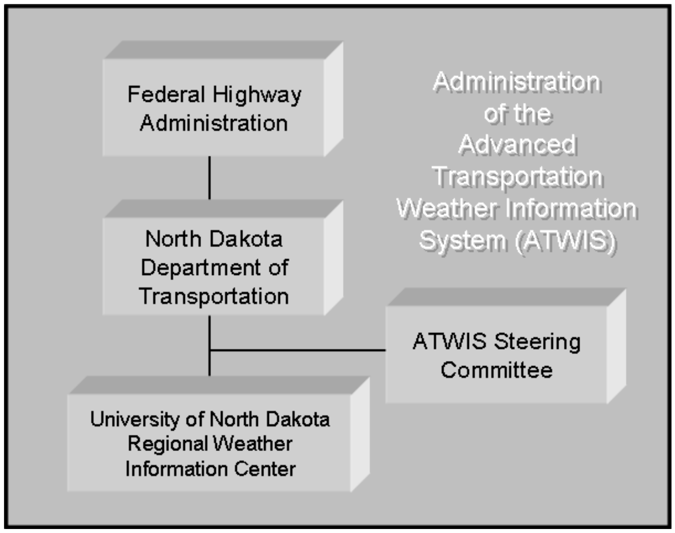

Figure 1. Organizational chart for the administration of ATWIS. The Steering Committee includes representations of the FHWA, NDDOT, SDDOT, and UND.

The ATWIS Steering Committee was chaired by the Director of the UND Regional Weather Information Center. Meetings were routinely held three times per year with the location of the meetings alternating between locations in North Dakota and South Dakota. An agenda for each meeting was circulated prior to each meeting to permit all Steering Committee members adequate input into meeting business planning. All financial and work plan matters were brought before the Steering Committee for consideration and majority approval. In addition to voting representatives from each of the agencies and organizations listed above, the meetings were open to the public and were routinely attended by other personnel from the member organizations and agencies.

Following guidance provided by the ATWIS Steering Committee, the UND RWIC worked between meetings with the North Dakota and South Dakota Departments of Transportation to ensure the efficient conveyance of weather information to the traveling public and to coordinate the receipt of road condition information from each state for use within ATWIS. The departments of transportation also became major users of the weather information as part of the road maintenance mission as the goals were modified. The results of this added usage of

ATWIS lead to an evolution of activities by the Steering Committee during the period of ATWIS research.

III. System Development Phase – 1995-1996

III.1. Mesoscale Models/Analysis

While weather observations provide valuable current conditions for the travel corridor and must be used to adjust forecasts when necessary, the value of weather information to travelers is greatest when it gives forecast conditions for a later segment of the travel path. Although technology did not exist to provide detailed site-specific weather forecasts for specific travel corridors, recent advancements in short-range weather forecast modeling did provide opportunities to support highly spatial and temporal resolution short-range weather forecasts.

Utilizing numerical weather prediction models that had been under testing and evaluation for the previous two years at the National Oceanic and Atmospheric Administration (NOAA) Forecast Systems Laboratory (FSL) in Boulder, Colorado, ATWIS meteorologists began work to utilize advanced technologies to produce short-range weather forecast products for discrete segments of the travel corridor. These forecasts were updated regularly to produce nowcast products, which reflect the changes to the model projections as based on hourly weather analyses.

Most of the National Weather Service (NWS) and commercial weather forecast information is derived from numerical weather prediction models used by NOAA's National Center for Environmental Prediction (NCEP). These models produce forecasts in intervals of 12-hours out to 120-hours (5-days). The use of these operational numerical weather prediction models has played an important role in the improvement of routine weather forecasting activities over the past three decades.

While extensive work has been conducted on improving these operational models by increasing their spatial resolution, the ability to resolve small-scale weather features had not progressed sufficiently to provide routine operational benefit to users, such as en-route ground transportation, who require fine-detailed information.

The response in increased mesoscale meteorological modeling had resulted in a cadre of sophisticated numerical models which, when tuned for specific regional features such as soil composition and terrain, could be used to resolve weather features of horizontal size of tens of kilometers. Unfortunately, the operational use of such models was not presently possible due to limitations in proper data networks necessary for model initialization and high computational requirements, which exceed the operational capabilities of regional NWS forecast centers. However, by the end of the decade the system proved that with proper initialization of these models and ever-decreasing prices of high-performance workstations, short-term forecasts could be issued operationally in relationship to precipitation, temperature, humidity, winds, and visibility for much smaller areas than are currently being used by the National Weather Service. This information was then tailored to application-specific decision support tools such as those necessary to support local and interstate transportation systems.

As part of research activities during this operational test, researchers at the University of North Dakota's, Department of Atmospheric Sciences, began working with a meso-β scale numerical weather prediction model to provide improved high-resolution guidance on precipitation, temperature, and wind forecasts. Using a model known as MM5 developed by the National Center for Atmospheric Research and Pennsylvania State University, efforts were made to adapt model features to perform in the Northern Great Plains.

Work focused on experimental studies of the effectiveness of FSL Local Analysis and Prediction System (LAPS) in providing analysis of meso-β scale features of temperature, moisture, winds, and visibility. Additionally, the modeling features of LAPS will be used to investigate the feasibility of automated short-range weather forecasts for road segments, using short-range, high spatial resolution models to provide 0 to 6 hour lead time notices of precipitation and visibility.

At the start of the test, the predictive component of LAPS was being executed at FSL on workstations with the capability of producing a twelve-hour forecast after three hours of execution. This long execution time made the operational use of the model in the nowcasting aspects of ATWIS unacceptable. However, ATWIS scientists, executing the model on a more powerful computer e.g., the UND Cray Y-MP, reduced the execution times to a length acceptable for operational application. The Cray Y-MP was used to execute the modeling functions of LAPS, while computing workstations were used to execute the analysis aspects of LAPS and provide visualization of both the analysis and model output to ATWIS forecasters located in RWIC. These guidance products were developed for use in a Decision Support

System (DSS) from which weather forecasts were generated for dissemination to information distribution points within a traffic test environment. This model was executed every three hours to produce short-range forecast guidance products.

III.2. Data Integration

The weather information used in this project was drawn from federal, state, and private data sources and managed by a sophisticated weather acquisition and processing system (Fig. 2). Federal data included the use of hourly surface weather observations reported by the National Weather Service, the Federal Aviation Administration, and the use of twelve-hourly upper-air observations made from rawinsonde sites across North America. In addition, data from WSR-88D Doppler weather radar data from the NWS was also utilized routinely in both forecast generation and data assimilation activities.

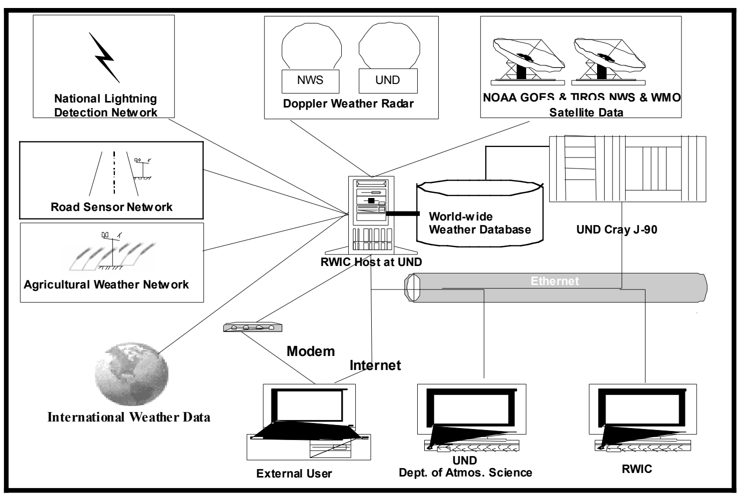

Figure 2. The data acquisition system of the UND Regional Weather Information Center supporting the ATWIS research and operational demonstration activities.

Included with this federal data were weather observations from mesonetworks of surface observation systems across the Northern Plains. These included systems supporting aviation, agriculture, and surface transportation (Fig. 3). The largest of these mesonetworks was the North Dakota Agricultural Weather Network (NDAWN). NDAWN consists of 45 surface weather monitoring sites across North Dakota, eastern Montana, and northwestern Minnesota. This information was collected hourly by the University of North Dakota, Center for Aerospace Science's, Regional Weather Information Center (RWIC).

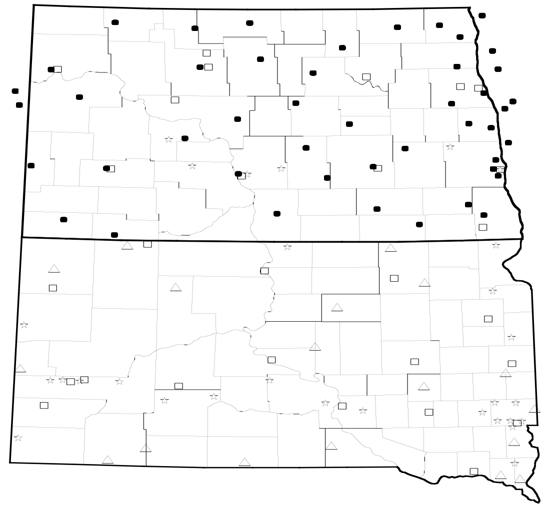

Figure 3. . Shown are the surface weather data sensors available at the onset of the operational demonstration in winter 1996-97. The solid dots represent the North Dakota Agricultural Weather Network, the rectangles represent airport weather observations, and the stars and triangles denote environmental sensor stations.

Other surface weather data included environmental sensor stations (ESS) that provided roadway weather and road surface condition observations from existing sites across South Dakota and North Dakota. These existing observational systems were provided by the NDDOT and SDDOT in cooperation with Surface Systems, Incorporated (SSI). During the duration of ATWIS, additional SSI ESS systems were installed at various locations within North Dakota and South Dakota, which enhanced the surface weather observation network, used in the demonstration project. This road weather information included air temperature, relative humidity, precipitation, and road surface temperature. The acquisition of this data was coordinated with the respective DOTs in both states. Data provided by the surface sensor is given in Table 1. Upon receipt of the ESS data, a quality control process was used to identify suspicious data that was then flagged for exclusion from the data assimilation activities. The quality controls were applied only to the atmospheric data except for gross error checks made on the pavement temperatures. Similar measures were utilized to quality control the non-ESS surface observations.

1. Surface Temperature
2. Surface Conditions (state of the roadway surface):
Dry
Wet
Deicing chemical presence
Snow/Ice Alert
Dew
Frost
3. Sub-Surface Temperature
4. Depth of Moisture
5. Percentage of Ice in Solution

Table 1. Environmental Sensor System parameters utilized within ATWIS

RWIC also served as the focal point for all weather data collection and was the primary weather analysis and forecasting center from which road weather forecast information was issued. In addition to the surface weather data and federally supplied upper-level data, RWIC also utilized Doppler weather radar data from the UND Department of Atmospheric Sciences' 5-cm research Doppler weather radar located on the UND campus. Weather satellite data to support nowcasting and forecasting operations was provided by the NOAA GOES 8 and from the NOAA TIROS series of polar orbiting weather satellites. The GOES imagery was received every fifteen minutes to provide important 15-minute updates of visible and infrared cloud imagery for winter and summer storm development assessment. This data was also crucial for initializing the atmospheric moisture fields for the mesoscale weather prediction models. In addition, satellite imagery (particularly in the visible spectrum) was useful during daylight hours in depicting fog conditions. Daily passes of the polar orbiting satellite provided detailed snow coverage information useful in temperature forecasting and provided vegetation information used in short-range weather modeling activities.

Data available from private sector lightning detection networks was valuable in the nowcasting and short-range weather forecasting process, thus obtained via the Internet. This resulted in near real-time analysis and display of polarized ground strike information, and provided important information regarding the development and severity of thunderstorm activity which often exceeds that available from radar observation.

III.3. Definition of Research and Demonstration Domain

The NDDOT and SDDOT road attribute data was required for the DSS, to provide road segment coordinates, skid numbers, surface types, bridge and culvert locations, and construction status. The latter information was acquired on a routine basis as it recognized this was not static information, but expected to change often during the year. This combination of weather information with road attribute information was a requirement for increasing the pertinence of weather forecast information. The combining of this information through a common user interface was required to provide coalescence of critical information (Fig. 4).

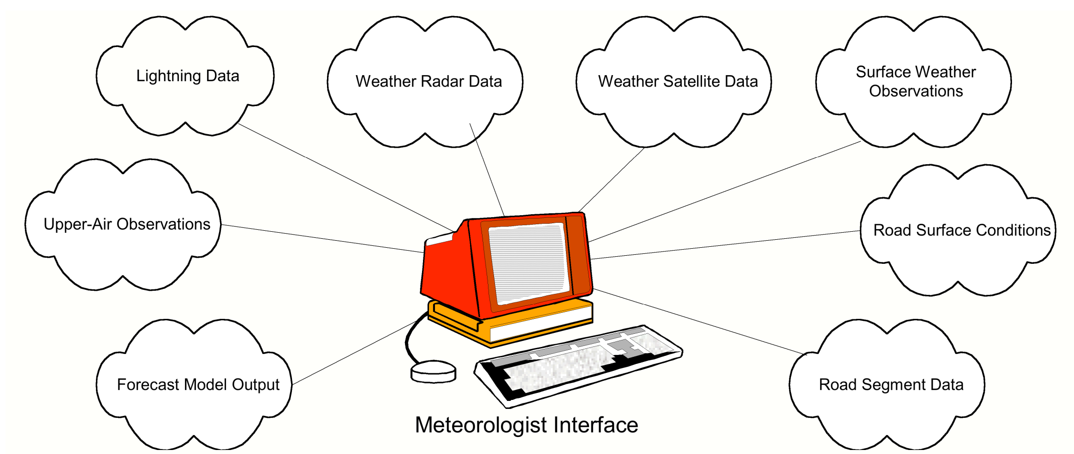

Figure 4. Conceptual diagram of the various data flows utilized to support road weather forecasting operations. The system combined to provide the Forecast Decision Support System.

III.4. Forecast Decision Support System (FDSS)

The high volume of observed weather data and computer-generated forecast guidance products had to be integrated with current and expected road conditions in order to develop pertinent weather forecast information. The formation of a DSS, a tool for making decisions based upon computer aided evaluation of complex information applied to specific problems, was needed to provide information designed to enhance traffic flow during changing weather conditions. Once forecast information was generated it had to be managed in ways such that immediate verification and validation was possible to permit forecast adjustments during rapidly changing weather conditions.

While much of the technology required to complete this project existed within the operational and research environment, it had to be brought together in a synergistic manner to provide the necessary support mechanisms to achieve the goals of the project. This included development of a DSS that provided efficient and timely forecast information to enhance the safety of the en-route traveler. This DSS combined the technology of weather analysis/forecasting with the computer representations of spatial and attribute information. It also required the development of an infrastructure for collecting, processing, and disseminating information in a framework, which permits concept validation.

The synthesis of weather analysis and forecast information with current weather observations and road conditions posed a significant task in data management and visualization. Integration of weather information with road attributes (data fusion) yielded the capability to simultaneously discern the weather and its potential impact on traffic flow. The decision support system for this project made it possible to identify specific travel corridor segments and immediately assess current and forecast weather conditions as generated from numerical and subjective weather analysis and prediction processes. Continued review and refinement of the current Decision Support System included enhancements to the forecaster interface enabling staff meteorologists to generate high volumes of travel segments forecasts for possible expansion both within current states and surrounding states.

This large amount of data fusion required a FDSS designed to manage data for timely dissemination of short term site-specific nowcasts/forecast. The FDSS's evaluation of complex information made it possible to identify a specific travel corridor and immediately assess present and forecast weather conditions.

III.5. En-Route Message Delivery

Since the work of this project was directed primarily towards assessing the feasibility of generating useful weather information for safe and efficient travel while en-route, it was important that a means be available to distribute this information to vehicles. In 1995 during the initial design of ATWIS various information delivery methods were explored. These included variable message signs, highway advisory radio and AM side-band radio. Considerations were given to Highway Advisory Radio, side-band AM or FM systems, or a specialized in-vehicle display. None of these three options were chosen either due to the high cost and/or low coverage. Instead, the use of analog cellular telephones was chosen because of the rapid growth in usage and the relative inexpensive cost to the program to deploy. While not prevalent at the time ATWIS was initiated, the technology continued to expand beyond analog cellular telephones to the present day where a broader coverage of digital cellular communications has developed across the major population areas of both North Dakota and South Dakota and most of the major Interstate and U.S. highways in both states. It was recognized at the time of the decision that the choice of cellular telephone was not the safest method when it results in distracted driving. However, it was an appropriate choice as it provided immediate delivery of information and resulted in almost statewide coverage across the two ATWIS states.

Seeking a large test bed from which to gather data on usefulness, accuracy, timeliness, and acceptance, the decision was made to create a special dial-in number or switch number for cellular phones. This solution provided a growing base of users and required no additional expense from the user to access the system. To facilitate cellular communications to support broad acceptance of a special dial-in number unilaterally across a large region, relationships were developed with cellular service providers across North and South Dakota. These include both side ‘A’ and side ‘B’ cellular communications bands. These companies which have been, and wish to continue as commercial partners for the continuation of the project, include:

- CommNet Cellular, Inc. The B-side carrier for the central and west parts of both North and South Dakota including the southeastern part of South Dakota. (acquired by Verizon Wireless)
- Glacier Lake Cellular 2000, Inc. The B-side carrier for the northeastern part of South Dakota only. (Acquired by Rural Cellular Corp.)
- Airtouch Cellular, Inc. The B-side carrier for the eastern third of North Dakota, and
- Cellular One, Inc. The sole A-side carrier for both states.
- Wireless North. A wireless carrier in North Dakota.

- Unicel. A new PCS wireless carrier in North and South Dakota.
- Quick Call Cellular. A cellular carrier in South Dakota.

Considerable development effort was required initially in programming the individual cellular companies to activate a special switch (#7233) or (#SAFE) at each cell location across the region. The cellular companies absorbed this programming expense as an in-kind contribution to ATWIS. In addition, a majority of them offer not only the service free to their customers, but the airtime as well. Having this switch at each of the cellular providers allowed the user to dial (#7233) or (#SAFE) and then connect to a computer telephony system at RWIC using landlines. Once connected to the RWIC computer telephony system, the user could begin the menu process of requesting/selecting road and weather information.

The computer telephony system used in ATWIS was a Lucent Conversant® MAP-100 (Fig. 5). This system was selected based upon its low cost and its adaptability to the development environment within RWIC. Specific importance was given to the UNIX operating system of the MAP-100. A critical design consideration of the computer telephony system was the reliability of the system both in its ability to handle large call volumes as well as the consistent up-time of the system. In an evaluation of operating systems done during the development of specifications for the computer telephony system, the superior performance and reliability of the UNIX operating system over competing systems, e.g. Microsoft Windows, was overwhelming. The Lucent solution utilized was one of only a few systems with this capability.

The MAP-100 was connected to a custom database developed to support the integration of road condition and weather information along all routes within the project test area. Within the database, which was designed to conform to accepted geospatial information system standards, were defining attributes for all highway routes including orientation, length of the defined route segment, a unique numbering system for all routes, and an indexing system for rapid data access. Referencing of road condition and weather information to specific route segments was facilitated through the database schema such that a brief query could quickly produce all data values required in a call transaction.

Figure 5. Image of a Lucent Conversant® MAP-100 used to provide computer telephony and interactive voice response support within #SAFE.

Associated with each database index and returned data value were cross-referenced, pre-recorded speech phrases. Based upon the coded road and weather information returned resulting from a user query using the computer telephony system's interactive voice response (IVR) capabilities, a speech phrase was concatenated in real-time to provide the information back to the caller. This permitted the generation of a place-based and seamless stream of information back to the end user according to their location or area of interest. Further, this permitted the scalability of the system to support the rapid expansion of the system capabilities that resulted due to the popularity of system use. The result was a two-way flow of information that effectively and efficiently joined user with provider and man with machine. The configuration of the complete computer and communications system is shown in Figure 6.

A sample of a transaction during a #SAFE call is provided in Table 2. After answering 4 questions detailing their location and direction of travel, the caller is provided a road condition report and short-range weather forecast. The computer system constructs an envelope around the caller's vehicle extending 40 to 60 miles (or 1 to 1 1/2 hours travel time) ahead in their direction of travel. A weather and road condition report is issued for this road segment to the caller using interactive voice technologies. On average, a single transaction data call lasts one minute and 20 seconds (1:20).

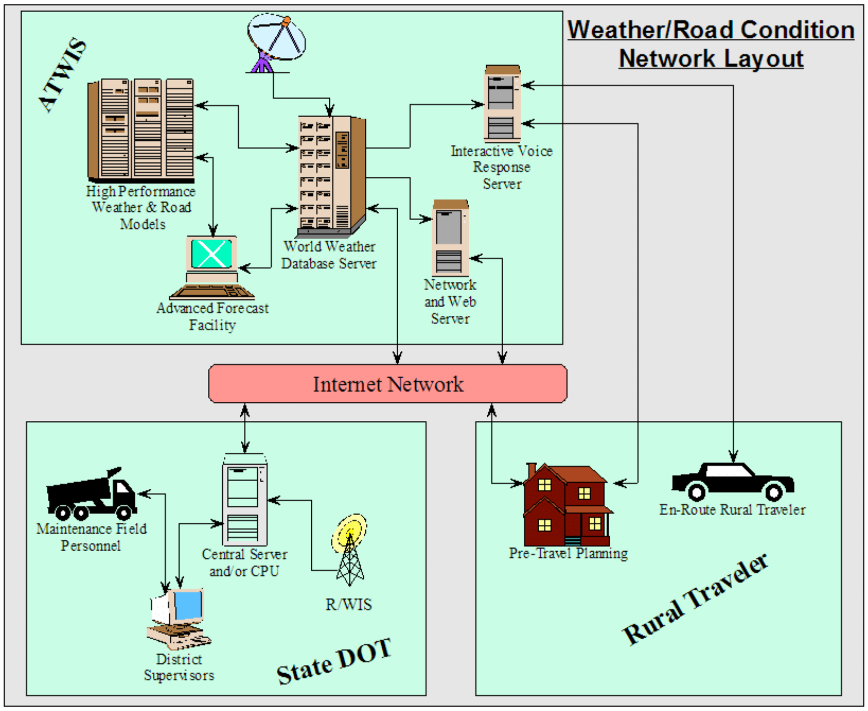

Figure 6. Conceptual diagram of the entire #SAFE en-route ATIS.

Growth and changes system-wide were made annually after a programmatic review of research, application, operation and commercialization by the project's Steering Committee. Beyond the results achieved within ATWIS, it is projected that future changes to digital communications in AM and FM radio transmission will result in dramatic changes in in-vehicle data processing capabilities. With this expansion of digital communications comes the opportunity to explore alternative methods of providing in-vehicle road and weather information through hands-free delivery. Beyond just the use within vehicles, the use of electronic personal data assistants to digitally receive textual and graphical information has already become established in larger metropolitan areas in the United States. Hence, the continued evolution of the #SAFE technologies developed within ATWIS will provide ever broader opportunities to provide advanced travel information.

#SAFE IVR Action (Audible Messages)	**User Input**	**Explanation of Activity**
#SAFE: Welcome to the #SAFE traveler information system. For North Dakota highways press 1, for South Dakota highways press 2, for Minnesota highways press 3.	***Traveler:*** Presses 2 for South Dakota	NOTE: This example demonstrates the multi-state integration of #SAFE that included the State of Minnesota by late 1999.
#SAFE: Enter the highway number followed by the pound sign (#)	***Traveler:*** Presses 34 for South Dakota State Highway 34.	NOTE: SD State Highway is an East/West Route
#SAFE: For eastbound travelers press 1, for westbound travelers press 2	***Traveler:*** Presses 2 for westbound travel.	
#SAFE: Enter the mile marker or exit number followed by the pound sign (#)	***Traveler:*** Presses 256 for mile marker 256, followed by the pound sign(#)	NOTE: The #SAFE computer constructs an envelope around the caller's location 40 to 60 miles (or 1 to 1 1/2 hours travel time) ahead of their reported location (the highway and mile marker provided by the traveler) and constructs a report. This report provides a route-specific road condition report and weather forecast that they may expect ahead along the route.
#SAFE: This road condition and weather forecast report is sponsored in part by the South Dakota Department of Transportation. For travelers on South Dakota State Highway 34 westbound from mile marker 256 traveling toward Pierre. Traffic speeds are reduced due to poor road conditions. Roadway is covered with patches of ice. Actual road conditions may vary from this report, motorists are cautioned to be alert to changing conditions. The forecast until 4:00 o'clock central time this Friday afternoon: Skies will be mostly cloudy becoming overcast. Visibility will be 5 miles changing to 2 miles. There will be occasional very light snow ending by 4:00 o'clock central time. Wind will be 9 MPH from the north changing to 3 MPH from the northeast. Temperatures will range from 21 to 25 degrees increasing to 25 to 27 degrees. To repeat the last message press 1. To begin a new information search press 2. If you have a question or comment about this system press 8. To end this call press 9 or hang-up.		NOTE: Message generated is a concatenation of pre-recorded speech phrases that represent every data element stored in the #SAFE database and which is updated as part of the continuing operational forecasting and road condition reporting within the system.

Table 2. An example of a typical #SAFE data transaction call where information (data) is conveyed to the end user.

IV. Demonstration Phase – Winter 1996-97 through Winter 1997-98

IV.1. Demonstration Deployment – 1996-97

The general geographic area used during the first year of operational testing was planned along 875 miles of the North and South Dakota segments of the Eisenhower Interstate Highway System. However, prior to start of the first operational year, this was expanded to approximately 2,200 miles of interstate and state highway travel corridors across North and South Dakota. The operational test included road conditions reports from the current reporting system with the departments of transportation of both states and merged with weather data provide by meteorologists. The latter information was designed to be updated every six hours. Each forecast was provided for a predetermined segment of roadway across the test area. All inputs, road conditions and weather forecasts were entered into a custom designed road and weather database. This database was then available for telephony access manually through cellular phone interaction by the traveling public.

Initial development and proof of concept testing of the FDSS, information dissemination, mesoscale modeling, and data acquisition systems were the main focus during the first year of field demonstration. While in-vehicle weather advisories were produced and made available to the public beginning November 1, 1996, maintenance specific forecasts for transportation operators began October 1, 1996.

This first year of the operational demonstration occurred in a winter that established new modern day records for extreme winter weather across the test area. Much of eastern North Dakota and South Dakota experienced over twice the average winter snowfall along with an unprecedented fifteen blizzards. The excessive snow accumulations resulted in major spring flooding across the eastern portion of the test area and many highways became impassable due to submersion under water. In addition, due to catastrophic flooding in Grand Forks, North Dakota, including the University of North Dakota, extreme measures had to be implemented to maintain the operational nature of the #SAFE demonstration during April through June of 1997. Although a mandatory evacuation was enforced throughout Grand Forks, North Dakota, provisions were made with state and federal agencies, along with AT&T – the long-distance service provider for the #SAFE program – such that no interruption of #SAFE occurred.

Within three months of commencing the demonstration operations, a comment line was added for users of the service to express their opinions or ask questions about the new system. Public comments were so supportive of the new system that they questioned why the system did not cover the remainder of the road network across both states. While site-specific road weather forecasting was viewed as an experimental improvement during this time, the success of this forecasting method created a larger public demand for the broader coverage of information provided over #SAFE (#7233). Road conditions, weather, flooding, construction, and accidents were among the list of improvements along with more frequent updates. By the end of the first year of the operational demonstration, the public's expectations had risen dramatically during just a single winter season.

A major finding of the operational demonstration was that the demand extended beyond periods of inclement weather. Prior to the operational demonstration, research expectations were that the system would be widely used during the winter and use would shrink significantly to almost no use during the summer. However, while use did reduce during summer months, there was never a day when the system went unused or an hour when information was not accessed in the entire first year of operations. This finding lead to the revisions in deployment plans for the second year of the operational demonstration to include construction information with each segment report. However, it was quickly learned during the development of assimilation methods to acquire this information that all road (including construction) and weather information would have to be integrated automatically within the #SAFE database in order to increase its usefulness and reduce the time lag between reporting and availability on #SAFE.

IV.2. Road Network Expansion and System Enhancement – 1997-98

As of November 1, 1997, the road miles covered by ATWIS increased to 3,200 miles (Fig. 7) across North and South Dakota. These additions included the remainder of US Highway 2, US 52 from Minot ND to Jamestown, US 281 from US 2 to the South Dakota State line. In South Dakota, additions included US Highway 281 from the North Dakota State line to US 14, US 12 from US 83 to the Minnesota State line, US 81 from Watertown SD to Interstate 90, SD State

Highway 37 from US 14 to State Highway 50, and State Highway 50 from State Highway 37 to Interstate 29. This expansion increased the road miles from 2,200 to 3,200.

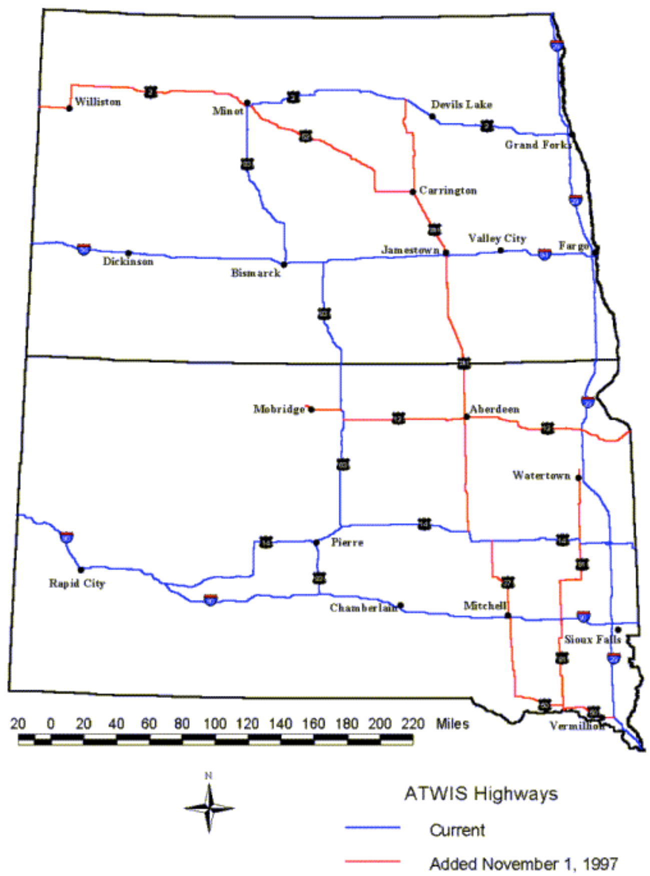

Figure 7. Travel corridors for #SAFE during the 1997-1998 operational demonstration. The total corridor included ~3,200 miles of roadway.

Realizing from the previous year the need for better automation in information assimilation, a definition matrix for specific road conditions was developed for use by the states to enhance and standardize the descriptive nature of the road/weather conditions along each segment of roadway. This matrix resulted in improved consistency in reported road and construction information and incorporation with the information delivery. Unfortunately, the merging of all data sources to include weather and weather related data, road conditions, and construction within a constant update cycle was still not possible. Due to the manual methods employed by each state DOT and the asynchronous manner in which the information was collected and disseminated by the DOTs, the information was not yet provided in a standardized format permitting reliable computer processing. So, while weather related data, model generation and operational forecasting products were automatically merged to produce a database supporting the weather for the computer telephony delivery, road conditions and construction information for individual road segments would continue to be manually entered into the system for integration throughout the second year of the operational demonstration.

The most significant operational improvements were realized in the weather modeling aspects of the project. The MM5 mesoscale weather prediction model had been used successfully in the operational environment of ATWIS at a grid spacing of 30-km and 10-km in predicting the development of short-term, small-scale weather systems. During the second year, research and refinement of the MM5 mesoscale model continued with experimentation with model grid resolutions of 4-km, 12-km, and 36-km. By fall 1998 a series of models were being run operationally on the UND Cray Y-MP supercomputer to support the weather forecasting activities. These improvements increased the ability to predict atmospheric events at the meso- and miso-scale. Resolving these fine-scale weather patterns along specific roadway segments was evaluated as to the efficacy in improving road weather forecast along the routes within expanded operational test area. While the forecasting benefited from this improved weather modeling capability, the benefit-to-cost was questionable at the time due to the high cost of supercomputer time. Fortunately, the visualization of the vast amounts of data generated by these models was facilitated by the contribution of a sophisticated visualization software package by Autometrics, Inc. The provision of this software was part of a major corporate matching contribution to the project to evaluate the capability of the Autometrics software to facilitate operational use of three-dimensional visualization tools in a weather forecasting operating operations. The software did perform superbly, but it too had a high computer overhead cost due to the processing requirements. By the end of the second year of the operational demonstration, it was concluded that until computing costs dropped dramatically the feasibility of using modeling domains below 10-km was not operationally feasible and that requiring such resolutions in a road weather forecasting environment would greatly limit the effectiveness of technology transfer to the surface transportation weather services community.

IV.3. Operational Deployment Phase – Winter 1998-99 through Winter 1999-2000

IV.3.1. Further Expansion and System Improvements

On November 1, 1998, #SAFE was once again expanded to cover a total of 4,800 miles across North and South Dakota, resulting in the nation's first statewide, multi-state, interoperable traveler information system under a single phone number. These additions included the remaining miles of road within the State of North Dakota consisting of US highways 52, 81, 83, 281 and all of US Hwy 85. South Dakota additions included US 85 from Interstate 90 to North Dakota, the remainder of US Hwy 83, US 16B, 79, 18, and 385 south of Interstate 90 to Nebraska, US 18 from US 79 to State 37, the remainder of US Hwy 12, and all of US 212. This expansion increased the road miles from 3,200 to 4,800 across the two states (Fig. 8).

The system began using the University of North Dakota's Cray J90 supercomputer during the 1998 winter driving season. The Cray J90 computer required approximately 1.5 hours (wall-time) to complete a nine-hour model forecast. A weather forecast and analysis system had been developed that incorporated sophisticated high-resolution weather forecast models capable of resolving local weather variations and providing greater site-specific detail over finer time scales to enhance the weather forecasting specific for each segment of roadway. Model forecast products for discrete segments of the travel corridor were generated and updated regularly to produce nowcast products (forecasts from current time to six hours into the future) which reflected the changes to the model projections as based on hourly weather analyses. In addition to the MM5 mesoscale model during this time, RWIC begin utilizing the Advanced Regional Prediction System (ARPS) mesoscale model for comparison analysis in late fall 1998.

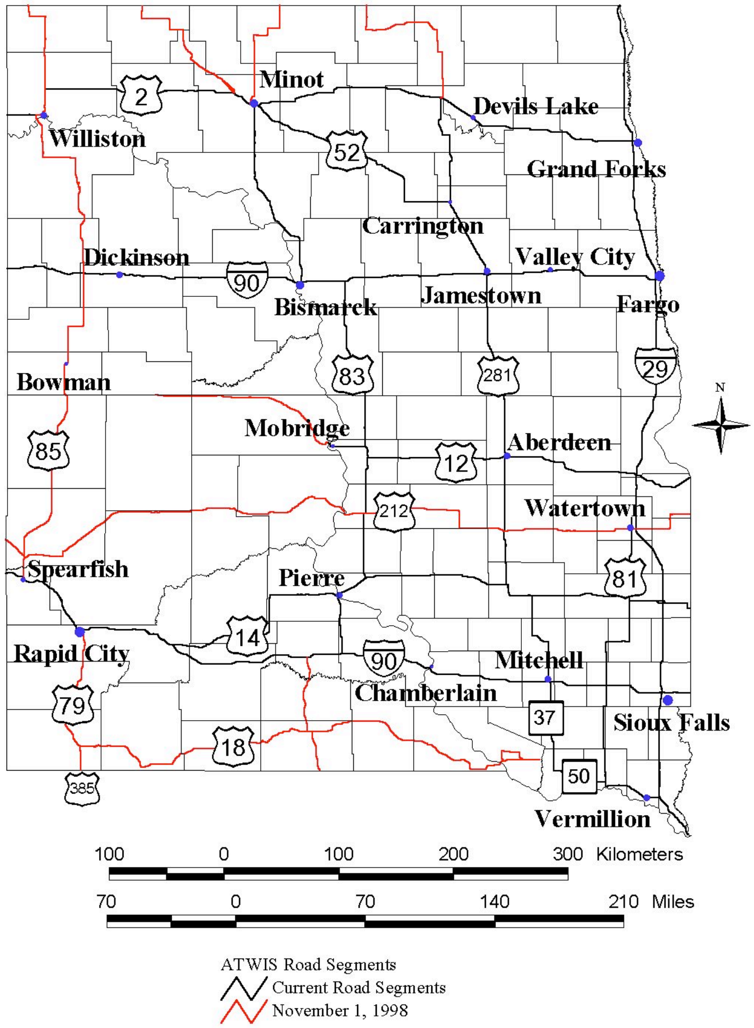

Figure 8. travel corridors for #SAFE. The included highways accounted for ~4,800 miles of roadway in the 1998 expansion demonstration project.

During this time, additional improvements included the forecaster interface to include greater flexibility in the descriptive nature of weather hazards a traveler may face. Focus on improvements to the integration of satellite imagery, radar, road condition monitoring, and sensor acquisition was improved resulting in reduced lead time from collection to operational use. While the FDDS provided unlimited site-specific forecast recommendations within the mesoscale domain region, the current forecaster interface inherently contained a limit to the number of processes an individual forecaster can operationally manage in a timely manner.

During December 1999, the NCAR/Penn State MM5 model was updated to the version 3 release. This provided Y2K compliance of the model and it also expanded the manner by which the land surface could be incorporated into the model. However, due to the ongoing winter operational demonstration, this additional capability for better defined land surface definition was not utilized as the existing method of using satellite remote sensing to define current land surface state did not have the sophistication to utilize the MM5 capabilities. It was subsequently determined that this capability would be added to the mesoscale modeling prior to the following winter.

IV.3.2. Initiation of Technology Transfer

As directed by Congress, a commercialization plan was developed for the transition of ATWIS #SAFE technologies into a sustainable framework. This plan was completed in September 1998 and established the principle operational and research guidelines for #SAFE in subsequent years. Critical to the implementation plan was the identification of commercial entities capable and willing to assume the technology and ensure its successful deployment as a sustained operational implementation. Deeming the operational demonstration to have been successful, the ATWIS Steering Committee recommended that the operations of the weather forecasting and road condition information service be out sourced to a commercial firm. After inquiries with companies within the private sector community deemed most likely to possess the capability to adopt the emerging technologies of #SAFE, only two private companies expressed interest in the commercialization activity. During discussions with the interested commercial firms, a detailed explanation of the required computational requirements and technical expertise (e.g. operational forecasting and information technology) were provided. One of the interested firms subsequently declined further participation due to the investment required in enhancing their computation and information technology resources to enable the use and deployment of the technology. The remaining interested firm, Meridian Environmental Technology, Inc. (Meridian), expressed a commitment and demonstrated the required infrastructure resources and expertise to support the operational deployment of the #SAFE technologies. The recommendation to proceed with Meridian as the commercial developer of the #SAFE technologies was approved by the ATWIS Steering Committee at the August 1999 ATWIS Steering Committee meeting. It was noted that Meridian provided a good candidate for sustaining the technology because of its early adoption of ATWIS-like technology for use in a similar en-route weather information activity across Minnesota and thus representing a relatively seamless transition of the #SAFE operations. This latter issue was of major significance to both North Dakota and South Dakota Departments of Transportation (DOT).

By the winter driving season of 1999, under a non-exclusive agreement with Meridian Environmental Technology, Inc., RWIC outsourced the daily operational forecasting activities in order to focus specifically on research efforts for improved surface transportation weather forecasting and decision support science. At the same time, Meridian began testing, reviewing and refining a new forecaster interface enabling increased forecast generation efficiency to support the transition of #SAFE into a sustainable product. This process ultimately greatly reduced the cost of production by increasing the meteorologist's efficiency in road weather forecasting.

This shift of the operational activities from UND to Meridian signaled not only the maturity of four previous years of research and development, but also demonstrated the success of the program in achieving its initial goal of providing an accurate, effective, and efficient method of providing en-route weather information. Further, the separation of the operational component of the program from the ongoing research and development strengthened the research efforts of the ATWIS by returning the university emphasis to its core strength as a research entity while utilizing Meridian's strengths in operational weather forecasting.

A benefit to UND of the outsourcing activity was that Meridian provided UND researchers access to its operational mesoscale modeling and access to its operational data resources to support university ATWIS research efforts. These enabled computational expenses associated with the Cray J90 at UND to be reduced significantly. The UND RWIC continued to host the computer telephony support for ATWIS message delivery until it was decided that a full transition of the UND information technology was appropriate.

Additionally, Meridian was able to break the technology barrier that had limited the merger of all data necessary to fully automate the integration of data from all sources. These improvements represented the beginning of the commercial viability of ATWIS as an affordable application for daily use across any state in the nation.

V. Sustainability Transition Phase – Winter 2000-01 through Winter 2001-02

With the beginning of 2000-2001 winter operations the operational forecasting effort of ATWIS was expanded to include all state trunk highways within North Dakota and South Dakota. This shift of the operational activities from UND to Meridian Environmental Technology, Inc. signaled not only a maturity of the research and development, but also demonstrated the success of the program in achieving its initial goal of providing an accurate, effective and efficient method of providing en-route weather information for a multi-state region. This was accomplished by Meridian's expansion of #SAFE to include all state trunk highways of Minnesota (Fig. 9). This latter activity constituted the first step towards sustainability as the effort in Minnesota was not funded as part of the UND ATWIS efforts.

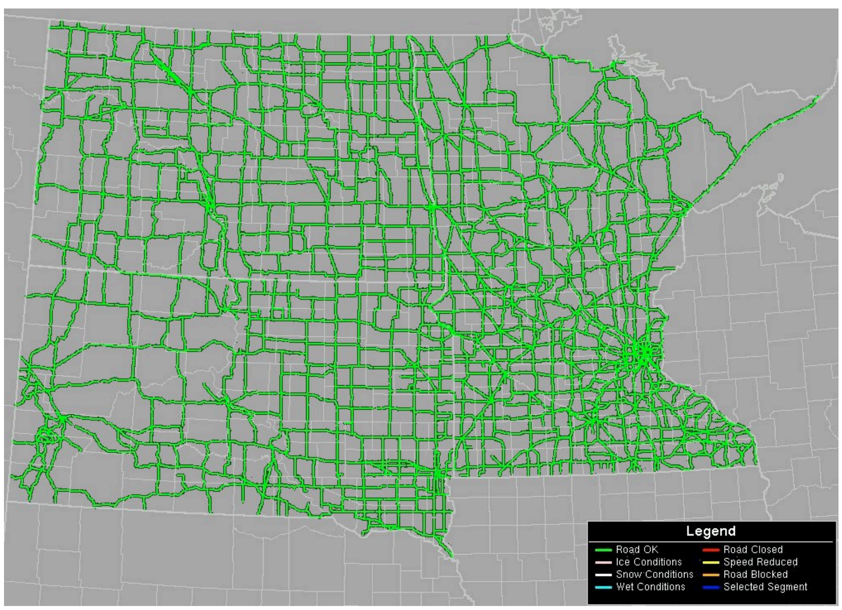

Figure 9. The addition of Minnesota using #SAFE technologies expanded the regional coverage from 4,800 road miles to all State, US and Interstate routes across all three states totaling approximately 16,000 road miles.

The ATWIS commercialization plan, while initially developed by RWIC and submitted for the ATWIS Steering Committee's review and approval, required a commercial entity to test, adjust, and apply the plan under actual business practices. The achievement of ATWIS sustainability by the expansion of #SAFE through a separate commercial contract demonstrated the capability of the ATWIS #SAFE technologies to attract sufficient funding to continue successful, sustainable business practices of the #SAFE product without further federal funding.

During the transition to commercial operations, research efforts continued at RWIC to advance the current state-of-the-technology in surface transportation weather forecasting and to spearhead evaluation of the effectiveness and adoption of this technology. This effort included the addition before winter 2000 of satellite remote sensing of land surface classification to enhance the mesoscale model initialization.

However, the level of support for in-depth research diminished over the last two years of the research program as the emphasis shifted completely to the operational deployment of the technology. While the responsibility for leveraging existing funds to promote the sustainability of the current ATWIS project existed with both UND and a commercial entity initially, over time this responsibility shifted entirely to the private sector as the ATWIS commercialization plan was implemented. Presentations on this commercialization activity, including the methodology of the #SAFE technologies, were provided on numerous occasions in open forums. These included presentations at the Annual Meetings of the American Meteorological Society, Annual Meetings of the Intelligent Transportation Society of America, and during invited presentations at meetings on Advanced Traveler Information Systems hosted by the Federal Highway Administration and U.S. Department of Transportation.

With the road weather forecasting technology barrier penetrated that held the operations cost above an acceptable cost/benefit analysis to make the #SAFE application commercially viable, Meridian replaced the technology utilized within ATWIS for IVR operations with a more innovative IVR delivery system that was more reliable and cost effective than the ATWIS Lucent Conversant MAP-100 technology. This latter involved a system that would increase the number of access points for travelers without requiring a political subdivision to invest in telecommunications infrastructure year round in order to meet only one or two peak use periods. Using their new IRV system design along with the remaining #SAFE technologies, plans were underway to incorporate all telephone systems statewide across the ATWIS test region. This plan was placed on hold as the FHWA had petitioned the Federal Communication Commission (FCC) for a new nationwide 'N11' number specifically for traveler information (e.g. 511).

#SAFE development and operation had been established and based on a clear set of operation and service rules designed to provide the traveler with information necessary to make a decision, not to make the decision for the traveler. These rules of basic operation for easy use through limited menu selections, route-specific information, cost limited to local phone charges to ensure access to all levels of income, multi-state interoperability to ensure access near state lines, comment line to address public concerns and interest, and 24-hour operation to ensure reliability were recognized and announced as the basis for the new national 511 guidelines during a meeting at the Annual Meeting of the Intelligent Transportation Society of America in Miami, FL in May 2000.

During 2000, Meridian, working with Nebraska Department of Roads and Nebraska Highway Patrol, built the Nation's first statewide 511 Traveler Information System. This first system was immediately interoperable with the South Dakota #SAFE system and represented the first commercial application of the technology. Additionally, this experience provided all states and private sector companies a blueprint of how, when, and with whom to engage during the process to ensure that all telecommunication systems across the state could accept 511 as a new N11 number. This first experience included such activities as working with the state Public Service Commission (PSC) to establish workshops for the telecommunication industry to understand 511 operations and requirements, switch construction needs, and associated cost. It established a model for tariff filings by the telecommunication industry to ensure that the cost was limited to the cost of a local phone call and protect the taxpayer from multiple charges for service.

During 2002 and 2003, Meridian completed the conversion of #SAFE in North Dakota and South Dakota to 511 and the addition of the Montana Department of Transportation. This signified achievement of the goal when ATWIS began to perform technology transfer and promote full commercialization of the entire suite of #SAFE technology i.e., road weather forecasting and information technology (Fig. 10). The deployment of the 511 program in North and South Dakota in late 2002 and early 2003 marked the final transition of the ATWIS #SAFE technology transfer into a sustainable, implemented technology from the university research effort. More significantly, the #SAFE system provided the national model for the rural 511 systems that have now been deployed regionally in over twenty states. The 511 road-weather information system essentially operates outside of the usual state Information Technology (IT) networks and thereby avoids some of the institutional constraints that were hindering the development of the integration component of the project. Important to North Dakota and South Dakota has been the transition from #SAFE to 511, which occurred without additional hardware or software purchases by either state.

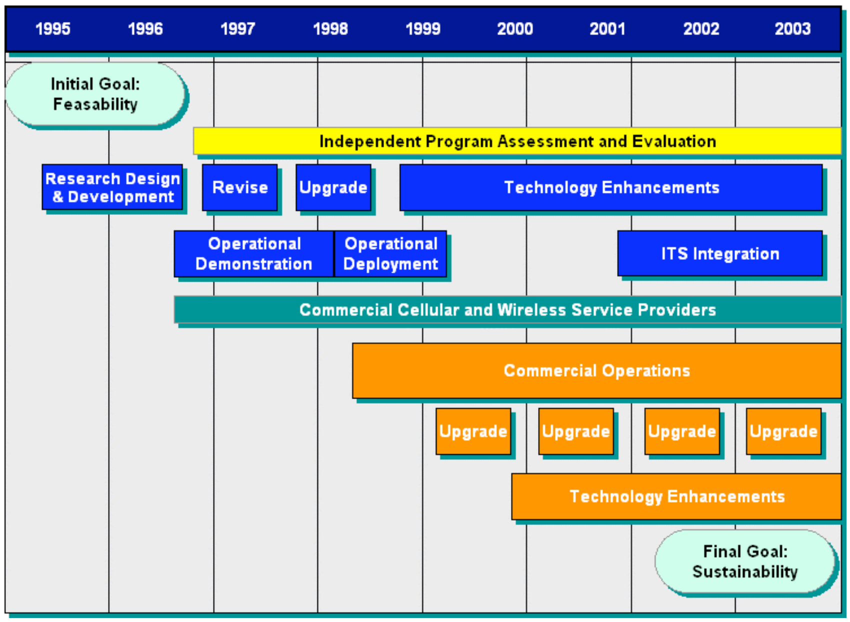

Figure 10. Timeline of development and commercialization of #SAFE within the ATWIS program.

VI. Expanded ITS Integration Phase

VI.1. ITS Integration Foundation Activities

Integration of transportation management systems is important to the establishment of a complete Advanced Rural Transportation Information System (ARTIS). The consolidation of Metropolitan Planning Offices, Emergency Management Systems, Highway Patrol Incident Command/Dispatch Systems, State Freeway Management Systems, Operations and Maintenance Systems, and Regional Traveler Information Systems, are a lofty, yet desirable goal of a fully integrated ITS regional architecture.

Current Environmental Sensor Systems within both North and South Dakota exist as stand-alone Road Weather Information Systems (RWIS) presently integrated only within ATWIS and are not routinely available for use with other transportation activities. In addition, a number of methods and interfaces for generating incident, road conditions, and construction reports by emergency management systems, freeway management systems, operations and maintenance systems, and highway patrol systems currently exist within their own environments without mechanisms for sharing of this information. These islands of information create a multi-layer collection of independent systems across each state as well as the region. While each information system may be opened to other departments within the state, delays in communication procedures reduces the value of this data and creates the need to duplicate similar types of information within each system. Integration of these systems will create a real-time road condition and incident reporting system statewide for all concerned agencies. Additionally, this integration would begin the process of decreasing duplication of information within a given system through the shared resources of information management. Additional systems during development may require integration as deemed necessary by the advisory committee.

The efforts of ATWIS have resulted in integrated Road Weather Information Systems (RWIS) not only between North and South Dakota, but with neighboring states as well. These data are integrated with the 511 capabilities in each state and thus support the other existing transportation management systems. The #SAFE traveler information systems across North Dakota and South Dakota now contain road condition information that has not been integrated into any seamless method of dissemination to the public or other agencies, let alone integrated with weather information. This ITS integration that has occurred to make this possible has established a benchmark for future systems for information integrations. Furthermore, the ITS integration by #SAFE has brought together numerous non-transportation weather resources in the first fully integrated road weather information system that is a part of the present traveler information system. These systems, including RWIS from all adjacent states, statewide agricultural weather systems across the North Plains, and the national NOAA weather data systems, now constitute a single integrated database of surface transportation related weather data.

The lessons learned and technology resulting from ATWIS subsequent to the end of the ATWIS program resulted in the enhancement of the present day road condition reporting system in South Dakota. This system has been derived from the technologies associated with the integration of a multi-layer collection of data systems used to form the database structures within ATWIS.

VI.1.1. STAKEHOLDER MEETINGS/COORDINATION

The University of North Dakota, in conjunction with the ATWIS Steering Committee, convened several meetings to evaluate the challenges and opportunities for the integration of transportation management systems across institutional lines in North Dakota and South Dakota. The stakeholders of the transportation management systems in each state were invited to participate in this discussion and provide guidance on future paths to promote better integration. Led by UND Regional Weather Information Center, meetings were conducted during spring 2002 with transportation, law enforcement, and emergency management officials in North Dakota and South Dakota in an effort to identify the data and institutional issues that must be considered to accomplish the integration.

VI.1.1.1. Data acquisition and reporting

Used in reference to integration, this was defined as taking the information provided to stakeholders and making it “speak” to them in a singular clear fashion. References to the greatest integration needs were made at the regional basis, with the various forms of information being passed through the each state’s emergency operations center (EOC). In these situations, data comes in from a variety of sources, with the National Weather Service (NWS) providing weather information and the DOTs providing road condition information. This system of data is linked to interested surface transportation weather service providers for their use. These data are available for distribution via phone and computer systems, with an infrequent briefing made available from the EOC. However, the distribution is not focused towards providing integrated information nor do the EOCs have systems in place for performing any automated integration of information. Any information integration that occurs is done by human integration through what is often referred to as swivel-chair integration. Further, neither North Dakota or South Dakota have at present a statewide transportation operations center (TOC) where a focus is placed on transportation management systems.

The summary of data integration desires for each state was quite similar. NDDOT would like to have a singular process/method for information gathering in order to avoid swivel-chair integration as they believe that there is too much information coming from multiple sources and locations. It was also their desire to access information via a medium other than the Internet (e.g., surfing the web for information). The SDDOT expressed a strong desire for a definitive source and repository of information that is distributed based upon individual needs. These needs would then require a measure of certainty that the information would be readily accessible when needed. In general, both ND and SD officials expressed a strong desire for an integrated information source that could be considered a ‘one-stop shop.’ It was believed that this would streamline their activities and enhance their decision-making abilities.

VI.1.1.2. Road and weather information sources

When asked about the sources of road and weather information they use, North Dakota and South Dakota transportation and emergency management officials indicated that they use multiple sources of information and do not rely on just one source. These include, but are not limited to private sector surface transportation weather service providers e.g. Meridian, the UND RWIC, the NWS, and Data Transmission Network (DTN). When distribution of this information to others within their agencies or to the public, the general methods used were typically UND #SAFE system, Internet websites, and DTN satellite distribution.

Specifically for the SDDOT, they use DTN for their source of weather radar, because “it is always on.” They receive additional input information from Meridian for maintenance weather forecasts. They provide the public information via #SAFE and their agency’s website. They still gather information from other sources, but would like to eliminate the extraneous sources for certainty of information. Further, they would prefer to receive most of their weather forecasts from Meridian as it is a source for more detailed information. In addition to receiving information from commercial information sites, there is also a desire to receive real-time data from commuters.

For the NDDOT, they currently receive information from multiple sources, and desires to reduce the information flow to select vendors for ease of integration of information. The possibility of selecting and training commuters for real-time observations was suggested.

VI.1.1.3. Inter-agency Information Sharing

Weather information is provided to other state agencies besides the DOTs. The information shared across agencies is sent via email, manual teletype, and a system called INLETS. Once again, varied sources of information are used. In addition to sharing information directly, the creation of a database pertaining to road conditions, permitting, and weather conditions would enable integrated resources and information distribution with a measure of certainty to the information's validity.

For both states there was a desire for an integrated information source for ease of access and certainty of accuracy. They also desired a closer integration of DOT and Highway Patrol (HP) systems, in addition to other state agencies. They would also like to improve their internal communications and coordination efforts to avoid situations where too many people become involved and hinder inter-agency operations. This creates a muddled view of defined responsibilities.

VI.1.1.4. 511 Implementation

Providing information to state agencies and commuters alike, 511 was envisioned to be an upgrade of the current #SAFE systems in place. A 511 implementation would aid in cross-agency integration and create regional systems for ITS deployments. [Note: Subsequent to the ATWIS project, both North Dakota and South Dakota adopted and have transitioned to successful 511 systems.]

The NDDOT would like to get more information from commuters, in regards to road conditions, in addition to receiving real-time condition reports from the HP. They believe that 511 would require increased feed points for sufficient support of 511 system and obtaining information from commuters is one such way of increasing feed points. They also believe that the presence of 511 would foster a closer operational relationship between HP and DOT management. From the results of #SAFE, both North Dakota and South Dakota felt that it demonstrated that there is a need for a marriage of weather and road conditions.

VI.1.1.5. Non-Standard Observers

The idea of trained observers, the use of commuters for observation of road and weather conditions, was considered by all parties as being a method that could be used in the place of requiring HP officers to report in real-time. The officials were reluctant to involve HP due to present workload and availability of personnel. The SDDOT was reluctant to use non-official observers because of concerns of data reliability. However, this variability in reporting could be remedied by standardization of reports using message sets such as contained in the Transportation Management Data Dictionary (TMDD). Using such a standard was felt to provide consistency and common terminology. However, the NDDOT was more receptive to selecting particular commuters and training them for site-specific reporting.

VI.1.1.6. Public Awareness and Increased Usage of Available Information

There was a common concern for increased public awareness of available weather and road conditions and reporting. This concern was compounded by the need for a centralized and integrated database of information, and single-source information for broadband outlet of information (web, phone, am/fm radio, etc.).

VI.1.1.7. Communications

Both North Dakota and South Dakota conduct road closures in coordination with the HP. In some cases, HP may request DOT maintenance services to sand or plow particular routes. To this end it was believed that there was a consistency of communication between the agencies even though much of this is human-to-human communications. There was a desire to create a consistent terminology of conditions to avoid confusion on the traveler's part both regarding travel in-state as well as when moving from one state to the next. Within North Dakota, the HP is directed to areas of concern in the event of inclement weather to aid in road closures and to provide real-time assessment of conditions for maintenance purposes. Reports are gathered at the district level and then passed to Bismarck if there is no response from the district.

In both North Dakota and South Dakota, the same terminology in communications is used. It was believed that this promoted effective cross-border communications and lead to a reliable system of communications.

VI.1.1.8. Integration of Operations and Security

The concerns of systems integration and operations of databases were expressed to be of high importance. The need for security throughout the system was needed, from firewalls to restricted access servers. Questions of where the servers are located, as well as how it would be serviced and operated, were approached. Information release, in regards to what was permitted to be released, the timing of information release, and protocol behind the release of information was also a concern. In addition to single-source servers, security issues and state guidelines must be met and these have become more complicated in recent years given world events. Further, there remains an issue of non-conformity of information systems and data formats. One particular example of this was geographical information system (GIS), which is a much-needed database in both states, but is different in formats followed.

For North Dakota the concern of security, in the form of firewalls, was something that identified as needing to be approached on an inter-agency basis. A system that permits people to access information from the outside of the system was desired, but there still remained issues of constituency usage. A concern was raised as to operational information technology support, as there were times of the day (nights) or week (generally weekends and holidays) when no one was available due to staffing issues. Regarding the decision to release information, in North Dakota, which has open record laws, information release is not too much of an issue. Regarding GIS standards, this was being addressed at the time of the meeting and the process of becoming standardized was occurring.

For South Dakota, the method of data collection and the conformity of systems integration was a significant concern. The logistics of operation and supportability of the system were also concerns. There was a requirement in place to meet state guidelines. Outsourcing of operations and security was suggested, but with reservation. SD maintains a closed policy on what equipment is being used and incident reporting. These reports would be available to HP, but not the public. The state's GIS is currently being built application by application, resulting in varied systems per agency and issues in data conformity and quality.

VI.1.1.9. Barriers

It was the consensus of the group that many barriers to integration and business activities would be met with barriers to progress. There was a clear need for additional funding and resources. It was expressed that although there would be some public investment up front, eventually the need for private investment would be needed to support such operations as 511. Unfortunately, the need for experts in the many fields of advanced traveler information systems e.g., 511, road conditions reporting and road weather forecasting was not being met. It was reiterated that there was a need for streamlining to a single-source system. Automation was seen as a partial remedy to this, but there would still need to be a position filled in the capacity of database maintenance.

VI.1.2. Data Integration

A strategic plan and needs based analysis of current systems will be performed to determine components requiring deployment to facilitate the integration process of all management systems. The National ITS Architecture will guide the strategic plan development and deployment of systems. The integration proposed between freeway management systems, emergency management systems, current advanced weather systems, road weather information systems, sub surface probes, traveler information systems, and accident reporting systems will be designed to reduce and consolidate similar shared information, enhance management and support decision making, and increase timeliness of data.

The National ITS Architecture provides a guide for the strategic plan development and deployment of systems. Infrastructure components supported for integration as part of ATWIS include:

A. Freeway Management
   1. Road Condition Reporting System - North Dakota Department of Transportation
   2. Road Condition Reporting System - South Dakota Department of Transportation
   3. North Dakota Road Weather Information System - North Dakota Department of Transportation
   4. South Dakota Road Weather Information System - South Dakota Department of Transportation

B. Incident Management
   1. Accident Reporting System - North Dakota Highway Patrol
   2. Accident Reporting System - South Dakota Highway Patrol

C. Emergency Services Management
   1. Incident Reporting System - North Dakota Division of Emergency Management Office

D. Other ITS Systems
   1. Sub-Surface Temperature System - North Dakota Department of Transportation
   2. Advanced Transportation Weather Information System (ATWIS) - University of North Dakota

ATWIS promoted the use of road conditions and weather information for the above activities to support the development of Statewide ITS Architectures in both North Dakota and South Dakota. The focus of the ATWIS ITS architecture efforts were associated with the flow of information to travelers using information service provider information after integration with various data resources (Fig. 11). At the end of ATWIS, it was still incumbent upon each transportation management system owner to work to develop a single data entry interface, providing input relating to its design, data output characteristics, size, quality, and security requirements as provided for in agency regulations and state law.

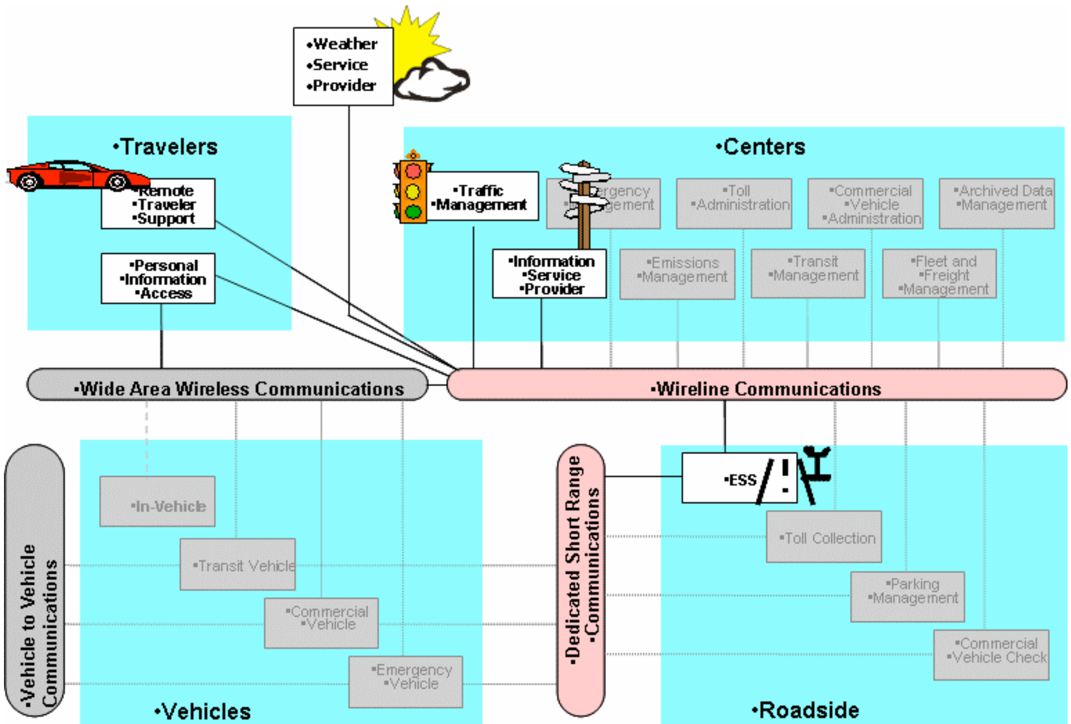

Figure 11. Schematic of the National ITS Architecture elements include within the #SAFE development.

A significant effort was made to ensure that the research and development incorporated appropriate ITS standards. As the ATWIS research spanned a total of eight years, a number of these standards evolved during the research activities. At various times during the development process a review was conducted to assess the conformance of the development to existing and emerging standards. In some situations, such as the NTCIP 1204 standard, ATWIS researchers actively participated in task force level activities to develop and refine these standards. An analysis of the ITS standards that are involved in the ATWIS #SAFE technologies are:

- SAE J2539 NTCIP
- data dictionary (SAE J2353)
- message sets (SAE J2354 and J2369)
- A Conceptual ITS Architecture: An ATIS Perspective J1763
- Messages for Handling Strings and Look-Up Tables in ATIS Standards (Draft) J2540
- Message Sets For External Traffic Management Center Communication (MS/ETMCC) TM2.01 (Draft)

- National Transportation Communications for ITS Protocol (NTCIP) - Internet (TCP/IP and UDP/IP) Transport Profile NTCIP 2202 (Draft)
- National Transportation Communications for ITS Protocol (NTCIP) - Object Definitions for Environmental Senor Stations NTCIP 1204
- Standard for Data Dictionaries for Intelligent Transportation Systems IEEE Std 1489-1999
- Standard for Functional Level Traffic Management Data Dictionary (TMDD) TM1.03 (Draft)

VI.1.3. INTERFACE/DATABASE DELEVELOPMENT

Major transportation management systems involving road condition and road weather information were integrated through the use of a single user-friendly interface designed to meet or exceed the information requirements of all participants. All information was capable of flowing two ways to ensure timeliness of data within each organization. RWIC designed the interface for data acquisition both as a transfer file or direct input from an agency. Technology was also developed to distribute necessary information to information service providers (ISPs), other agencies and traveling public reducing manpower requirements for dissemination. It was intended that routine traveler information systems, including web based text and map products, telephone message systems, and broadcast notification be automated to reduce lead time and increase efficiency. This integration project worked closely with the ITS planning groups developing a State ITS architecture plans in both North Dakota and South Dakota. Throughout, the National ITS Architecture was used as a guide for processes, data flows, interoperability, as well as physical and logical architecture design.

The rural nature of the highway system within the two states required that ITS provide methods and processes to reduce the time it previously took to disseminate information to both the traveler and all necessary agencies. By reducing the length of a #SAFE data transaction to under 90 seconds (on average) and presenting the traveler with no more than four questions to arrive at the answer they desired, an efficiency in information dissemination was achieved. While integration of the weather information system into a management system provided most of the scientific research within ATWIS leading to additional detailed road weather data for management that did not exist previously, the accomplishment of integrating additional information derived state road condition reporting systems provided innovative accomplishments in a next-generation traveler information system that continues to be operational across both states.

VI.2. ITS Integration – Spring Load Restriction Prediction

The process of ITS Integration involves addressing challenges of expanding applications of information to address present problems. A problem presented by the NDDOT that required a new approach in information and application integration was associated with determination of timing and duration of spring load restrictions for critical highways.

During the winter, exposure of the road surface to temperatures below freezing results in a cooling of the roadbed and soil immediately below the road surface. Due to conduction downward of these cold conditions over the course of the winter, the freezing level in the soil migrates downward during the winter months. Because of the natural heating and outward conduction of warmer temperatures deep within the earth's crust, a temperature below freezing is not a natural state for deep soil. This resistance to cooling by the natural warmth of the earth's crust serves to limit the depth of the freezing level. The mean air temperature therefore largely controls the annual variation in the depth of freezing over the course of the winter.

Another significant factor controlling the depth of the freezing level is the amount of soil moisture present. This soil moisture acts as a retardant in the downward movement in the freezing level through the release of latent heat due to condensation. As the moisture in the soil changes to ice, the release of latent heat results in a residual warming that helps to insulate deeper levels of the soil. Typically, the location of the line of demarcation separating the level of frozen moisture from the non-frozen soil is referred to as the frost depth and the layer of frost in the soil is known as the frost zone.

In the spring the upward movement in the frost depth is similar to its downward movement i.e., it is largely controlled by the mean air temperature. However, due to the low albedo of road surfaces and the increased solar insolation into the spring, the frost depth beneath a road surface may actually move upward more rapidly than the surrounding sub-soil areas away from the road surface. But, as the frost in the soil returns to water, there is a retarding effect due to latent cooling that acts to slow the upward movement of the frost depth. The warming of the soil typically will occur more rapidly in the near surface layers, since due to a phase offset in the temperature flux over a distance downward the process of the frost depth moving downward will continue until a downward flux of warm conditions overtakes the downward moving frost depth.

As the top layer of the frost zone melts, water will accumulate between the base of the road surface and the top of the frost zone. Since the frost zone beneath the warming surface layer does not permit the soil moisture (water) to permeate downward, this water will remain suspended in the soil resulting in a higher concentration of water to soil matter. Dependent upon the amount of soil moisture contained in the frost layer, this excess moisture can result in unstable soil conditions that make travel over the road surface abusive to the road surface/road bed. It is during these conditions every spring when roadbeds begin to warm, safety and operations issues exist on when and where to impose weight restrictions for commercial trucking and place restrictions on what travel is permitted.

To address the atmospheric factors leading to appropriate designation of spring load restriction, it was necessary to refine existing mesoscale and synoptic scale modeling technology that were previously used in support of en-route traveler weather information. Modification of these methods permitted these resources to be used to better understand how to predict the future conditions of the road surface and roadbed. In order to better understand and forecast these conditions, it was necessary to deploy field sensors to determine temperature profiles throughout the sub-pavement down past the frost zone. These observations were used to support development and testing of a model designed to predict road surface and subsurface freezing and thawing that can cause damage to pavement integrity under heavy vehicle loads. The objectives of the model were to support more efficient and timely implementation of travel restrictions for heavy or commercial vehicles, to minimize the duration of imposed restrictions, and to minimize maintenance costs associated with repair of damaged pavement.

This work required the design and installation of instruments beneath the road surface at various locations across North Dakota. These instruments provide sub-soil temperatures profiles that are useful for initialization of sub-surface thermal models and for the validation of these same models during the winter and spring months. Using an existing pavement temperature model developed and used within the FHWA Long Term Pavement Performance (LTPP) program and scientific expertise on sub-surface modeling provided by Meridian Environmental Technology, Inc., these observed values were used to model the thermal diffusion properties. As the probes were installed, core samples of the soil were used to characterize the soil type at each test location (Fig. 12). These cores provided thermal and permeability properties of both the undisturbed soil and the roadbed and were important in the understanding of the diffusion process.

Figure 12. Picture of NDDOT personnel as in the installation of a UND sub-pavement temperature probe used to support spring load restriction prediction research.

Six probe sites were established with a geographical distribution of northwest, southwest, south central, north central, northeast, and southeast across North Dakota (Fig. 13) to coincide with the varying climate zones across the state. Each site measured soil temperature at twelve levels to a depth of two meters. Attempts to measure soil moisture were hindered due to the lack of cost effective methods to install such probes without significant excavation of the road. In fact, the lack of acceptable sub-surface probes for use beneath the road surface required a significantly greater period of sensor design and installation and resulted in a two-year delay in model validation. Each of the sub-surface probes was installed adjacent to an existing environmental sensor stations. These ESS sites provided measurements of air temperature, pavement temperature, and precipitation. Data collection has been made at 10-minute intervals continuously since April 2003. Where possible, siting of the probes were also made in the vicinity of existing North Dakota Agricultural Weather Network sites to provide deep soil temperature and moisture conditions. These latter criteria were established to permit correlation with off roadway sites and to possibly permit generalizations resulting in greater observational support for future forecasting efforts.

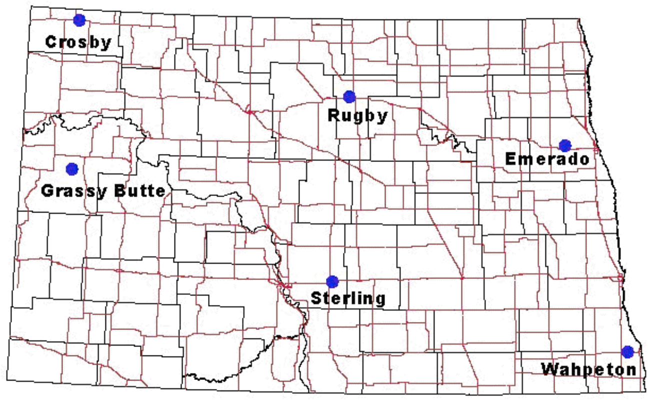

Figure 13. Map denoting the locations of UND sub-pavement temperature probes used in spring load restriction prediction research.

The delays described above lead to the work on model validation extending beyond the end of the ATWIS project period. However, results of the model development subsequent to the end of ATWIS program funding has provided a successful validation of the initial methodology (Fig. 14 and Fig. 15) and has resulted in an experimental model for further testing and refinement during subsequent years that continue to present. It is expected that the research and development of a fully operational sub-pavement conditions forecasting system will require an additional three to five years; however, operational use of the system in a demonstration and testing configuration began with the thawing conditions in 2004.

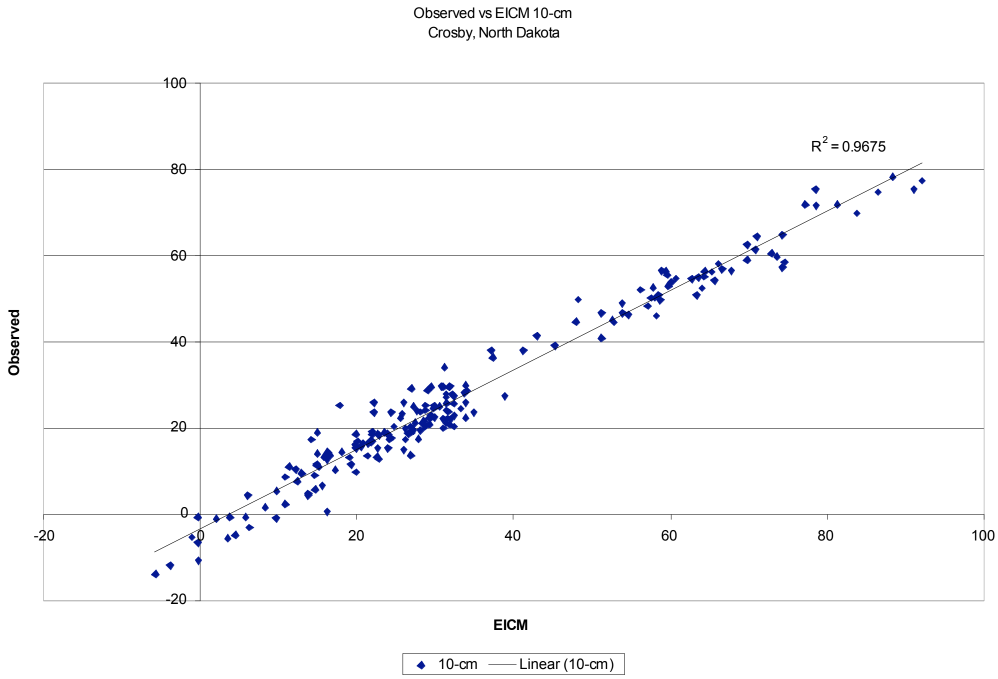

Figure 14. Sub-pavement condition model output versus observed sub-surface temperatures at a depth of 40-centimeters. Location is Crosby, North Dakota for the period from September 1, 2003 to March 16, 2004.

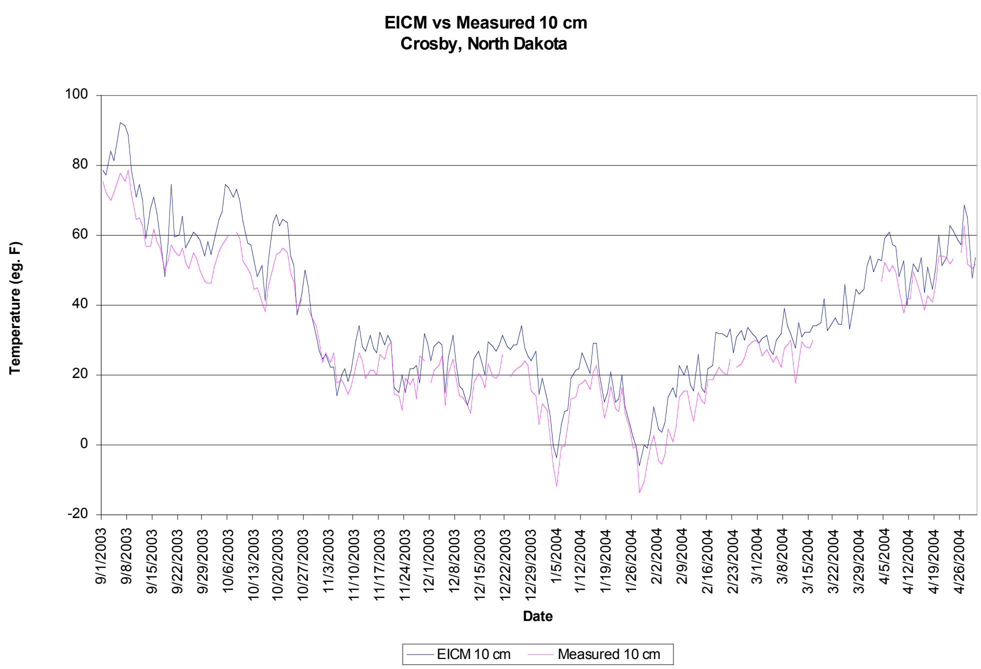

Figure 15. Relationship between the sub-pavement temperature model and observed temperatures at a depth of 40-centimeters. Location is Crosby, North Dakota for the period from 1, 2003 to May 1, 2004.

VII. Evaluation Goals

The goal of ATWIS was to provide a demonstration and evaluation of how current technologies in mesoscale meteorological analysis and forecasting could be effectively used to produce precise spatial and temporal weather information integrated into an ATIS for safer and more efficient operations.

To accomplish the efforts of ATWIS, four specific goals were established. The following section will address each of these goals. The evaluation of the feasibility of the technology, the effectiveness of the technologies, and user acceptance was evaluated respectively through the statistical validation of the scientific and operational methods, development of critical partnerships that by their existence demonstrated the worth of the endeavor, the independent sampling of travelers passing through the travel corridors, and the independent sampling of the winter maintenance community in both participating states. This independent sampling effort was performed by an outside agency to maintain independence in the evaluations. The effort utilized a modern survey instrument design, which provided for statistical evaluation of responses. The scope of the evaluation was to determine the effectiveness of the #SAFE cellular application of an Advanced Transportation Weather Information System (ATWIS) technology in accordance with the goals and objectives of the program. Since the long-term goal of the #SAFE system is to establish a long-term supported program to continue to provide advanced transportation weather information to the traveling public and the transportation infrastructure in which it exists, it is crucial to understand the level of acceptance of the services and information provided. The Bureau of Governmental Affairs at the University of North Dakota and the Western Transportation Institute at Montana State University conducted the independent evaluations.

In addition to the independent and self evaluations performed by ATWIS, the U.S. Department of Transportation ITS Joint Program Office contracted with Battelle Memorial Institute to conduct an independent evaluation (Cluett and Kitchener, 2004) of the earmark project in order to better determine and document the benefits of the rural ITS application of the ATWIS efforts.

In addition to the evaluation measures mentioned above, one additional measure of effectiveness that is included in this evaluation summary comes directly from the users of the system as they are using #SAFE. During the initial operational testing, a customer comment line was provided to increase feedback from the traveling public. Since that time, a number of comments, questions, and suggestions have been left for the program manager. These comments were recorded word for word and reported regularly to the steering committee.

VII.1. Evaluation Results

The evaluation of ATWIS and the technologies leading to the development and deployment of #SAFE are provided below for each of the individual goals as set out in the original proposed work and amended by the ATWIS Steering Committee to include the assessment of #SAFE benefits to the winter maintenance community in North Dakota and South Dakota.

VII.1.1. Evaluation Goal One

Goal: Ongoing development/integration of site-specific nowcasting/forecasting weather information into a decision support software environment to support analysis and interpretation of traveler information needs.

Methodology: Systematic statistical verification of the forecasts generated.

Results:

The validity of the analysis and forecasting were monitored through systematic statistical verification of the analyses and forecasts generated. Numerical calculations were made to validate the forecast accuracy utilizing the observed conditions reported by the available sensor stations (either ESS or airport observations). Every forecast segment of roadway served as a validation point. During the first year the number of validation points across the test region was limited to 36 points. By the final year of the demonstration, this number had grown to 140 points. With each validation point receiving a new 6-hour forecast every three hours, this resulted in approximately one and a half million forecast points over the validation period from October 1996 through July 2001. This value increases by almost a full magnitude if each hour of the six-hour forecast is considered. The resulting magnitude of forecasts quickly made the feasibility of validating every forecast unrealistic. Therefore, a random sample of six validation points (routes) was selected for each forecast with just one hour in the full forecast period validated. In addition, due to the lack of sufficient site-specific information on cloud, visibility, and precipitation, the verification efforts were limited to temperature, wind speed and wind direction. The validation criteria used were that a forecast was considered accurate if the temperature was within three degrees Fahrenheit at the valid time, if the wind speed was within five miles per hour at the valid time, and the wind direction was within fifteen compass degrees at the valid time.

Overall validation scores were stratified to provide performance information based upon time of year. Performance skill was measured by computing accumulated absolute error for the verified forecast parameters. Figure 16 provides the mean absolute error for the forecasted air temperatures for each year in the validation study. A decrease in the annual mean absolute error is seen generally with increasing years. The higher values during the first two years are likely attributable to the harsh winter of 1996-97 and the difficulties experienced with integration of mesoscale weather prediction models into the early forecasting environment. The improvement in the latter three years is also likely due to the shift of the program to a commercialization effort where a more sophisticated operational forecasting environment existed than was present in an academic setting.

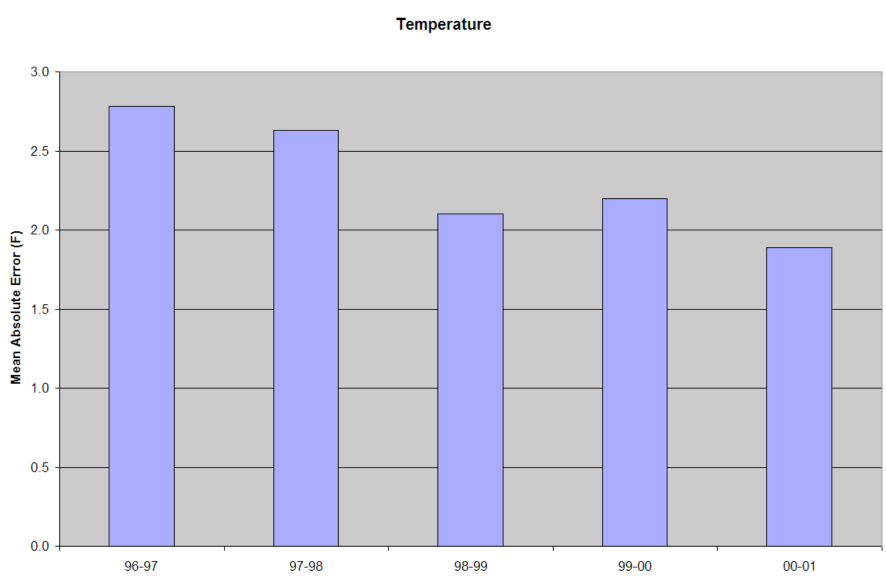

Figure 16. Mean absolute error in #SAFE air temperature forecasts during a five-year validation effort.

Figure 17 provides the mean absolute error for the forecasted wind speeds for each year in the validation study. Similar trends are seen for these forecast errors as seen in the air temperature forecasts with a greater impact noted for the first year of operations. The first winter also had fifteen blizzards across the test domain where following years had few such storms present.

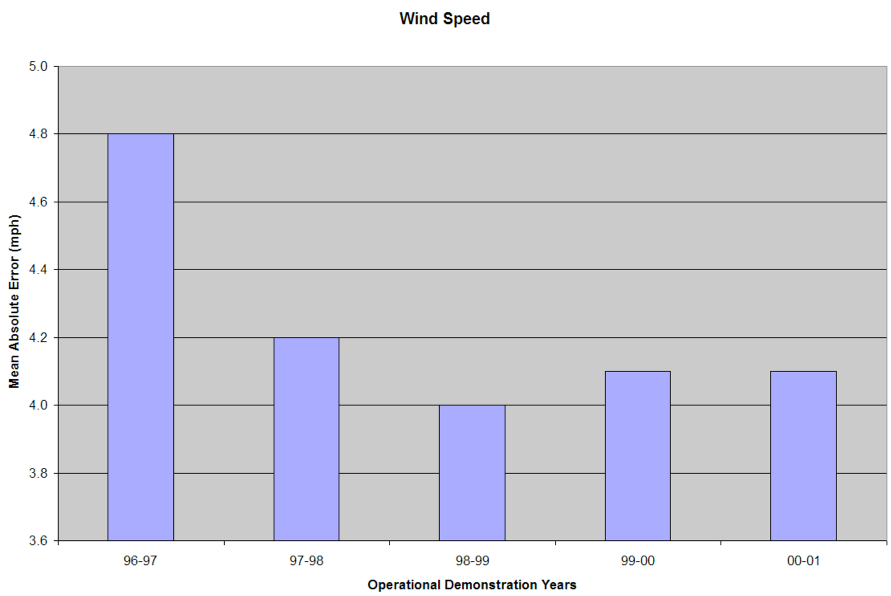

Figure 17. Mean absolute error in #SAFE wind speed forecasts during a five-year validation effort.

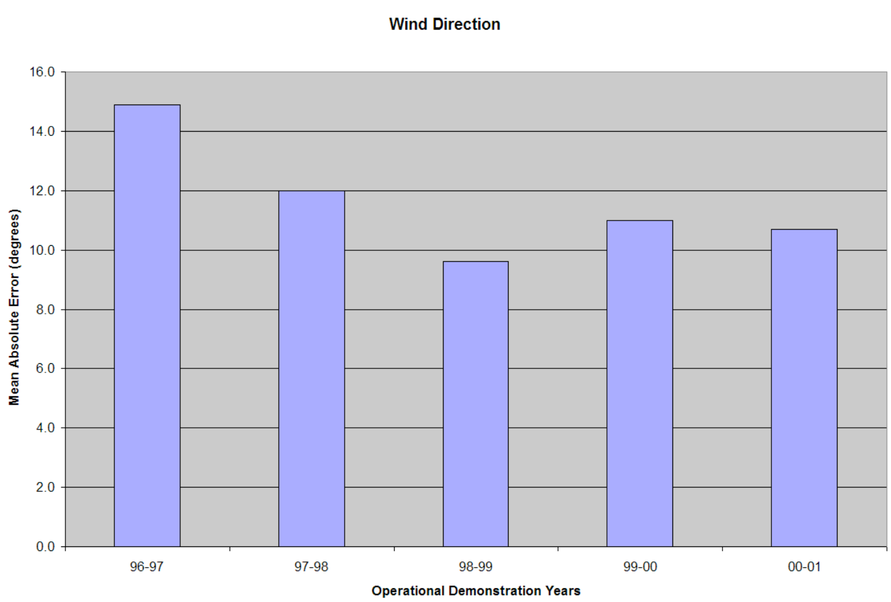

Figure 18. Mean absolute error in #SAFE wind direction forecasts during a five-year validation effort.

Figure 18 provides a similar representation of the mean absolute errors but for forecasted wind directions. The mean absolute errors in the wind direction are more consistent across all the validation years. This is indicative of the greater difficulty in predicting a precise wind direction as opposed to the wind speed, which has significantly better statistics.

Figure 19 depicts the variation in mean absolute errors for each of the forecasted parameters validated as a function of season of the year. The results are generally as would be expected in that the more difficult forecasting challenge exists in winter into spring. Especially during the summer, conditions across North Dakota and South Dakota become more quiescent and easier to predict. Exceptions to this are during thunderstorm events. In the validation no recognition was given to the presence of thunderstorms owing to the random nature of the validation site selection every three hours.

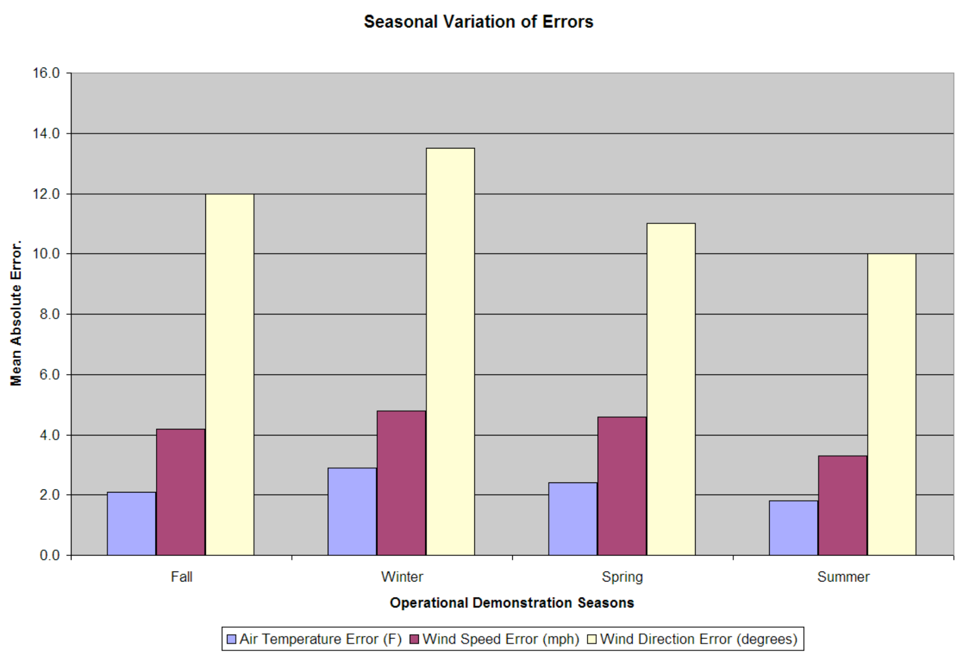

Figure 19. Seasonal variation in errors for the validation parameters during a five-year #SAFE forecast validation effort.

Finally, in Figure 20 the percentage of 'correct' forecasts is provided for each of the validated parameters. The results show the difficulties encountered during the initial years, but the continual improvement in the system over time. It should be acknowledged that the high frequency of the forecast validation sampling e.g. every three hours and the short-range forecasts that were being validated would be expected to yield the high skill level present. However, since the philosophy of the ATWIS program was to provide short-range forecasts for travelers traversing one-hour travel time route segments, the span of the forecasts over six hours does suggest that the reliability of the information is sufficient to support a travelers needs for six-hours or 360 miles of travel planning. Further, figure 20 substantiates the capability to use site-specific forecasting to support en-route and travel planning decisions. And the continual improvement of the forecasting skill over time represents both the continual advancement of the technology as well as the capabilities of the surface transportation weather services community.

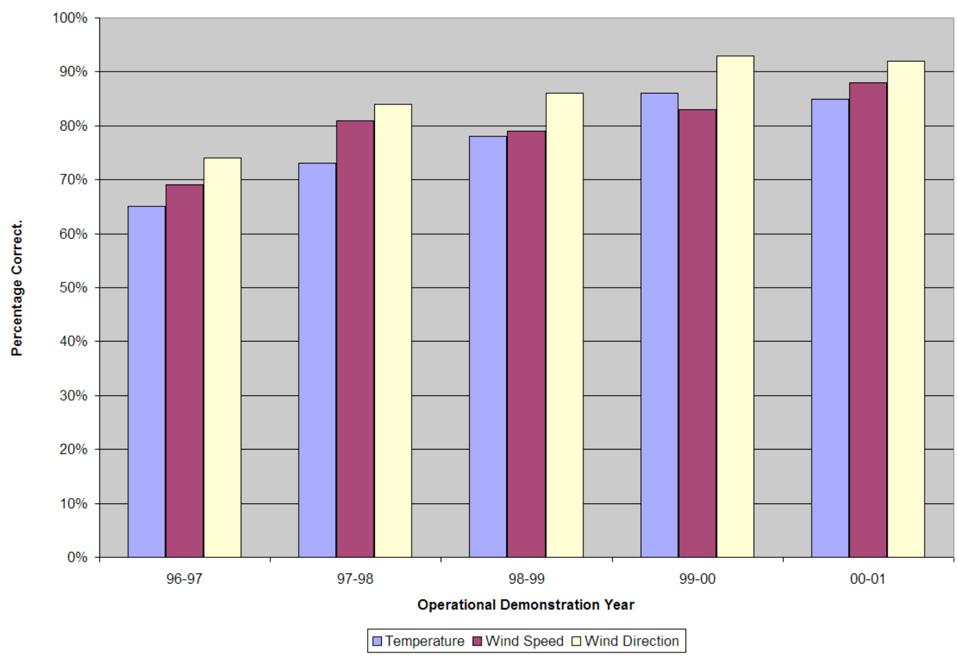

Figure 20. The percentage of 'correct' forecasts of air temperature, wind speed, and wind direction during the first five-years of the #SAFE operational demonstration.

VII.1.2. Evaluation Goal Two

Goal: Develop / implement effective information distribution procedures to the travelers.

Methodology: Memorandum of Understanding with telecommunication companies, track FCC licensing of new markets.

Results:

Memorandum of Understandings (MOUs) where signed with four cellular providers across North Dakota and South Dakota during the summer and fall of 1996. At this time, this represented the only cellular providers in the two states.

As the program progressed, it was necessary to track not only new licenses issued by the FCC for PCS or digital systems, but to track the industry as market areas changed hands. This changed the footprint coverage of each company's reach as they sold or bought new market areas. During the period of the ATWIS project, North Dakota and South Dakota contained eight wireless companies, four cellular and four digital providers. Of the original four, only two still exist at the end of the project, while the coverage of wireless access across both states have improved greatly.

VII.1.3. Evaluation Goal Three

Goal: Estimate the marketability and user acceptance of the provided weather information leading to the transition in commercialization.

Methodology: Independent evaluator will perform annual customer market surveys across the two-state region.

Results:

With limited advertising the first year, this system handled over 55,000 accesses to the weather forecast database from cellular telephones. Information for specific road segments was accessed following a menu-driven procedure using touch-tone commands.

The purpose of the #SAFE surveys were to investigate system users' perceptions of the effectiveness of the cellular based #SAFE road conditions and weather forecasting system being used in North and South Dakota. The results of the survey were used to improve the quality of services rendered as well as provide insight into the potential development of a long-term user fee supported program to eventually provide this information.

Three surveys of cellular telephone owners, one telephone survey and two mail surveys, were conducted between the spring of 1997 and summer of 2000. The telephone survey and the first mail survey were conducted by the UND Bureau of Governmental Affairs (Gannatasio, 1998). There surveys were to evaluate #SAFE clients from random samples of cellular telephone owners in North Dakota and South Dakota.

Their evaluations of #SAFE users of the Advanced Transportation Weather Information System were as follows:

- A mail survey of cellular telephone owners, conducted March 1 – April 15, 1998. 2862 questionnaires were mailed out originally with 837 completed questionnaires being returned.
- A telephone survey of 600 cellular telephone owners, conducted November 16 – 18, 1998.

The number of telephone interviews was selected in order to produce a margin of error rate in the +/ - 4 percent range. In the same vein a large number of mail questionnaires were mailed in order to yield a return rate equal or better than that of the telephone survey. This produced a margin or error rate in the range of +/- 2.5 percent. The response rate of 837 from 2862 mailed questionnaires, or 29.95 percent, was relatively good and assured a response number sufficient to provide sample reliable. When the two surveys were compared demographically, they look remarkably similar. The only exception was the higher percentage of rural respondents in the mail survey and a higher percent of city respondents in the phone survey. This exception was argued to be due to the difficulty of reaching rural residents during telephone interview times.

The summary of findings in these early surveys was that:

- Less than half the population surveyed was aware of the existence of #SAFE. Ten percent (10.5%) of all persons surveyed reported using the #SAFE number. But when controlled from awareness the users numbers increased to eighteen (18.5%) percent of the population and
- Highways signs were the most frequent way people reported becoming aware of #SAFE, followed by radio radio/TV advertising. No other means of information reached 10 percent of the population. Residents of North Dakota were much more likely to acknowledge the highway signs as a source of awareness.

While the Bureau of Governmental Affairs had agreed to perform the annual survey associated with the external evaluation of ATWIS, the changes within the Bureau of Governmental Affairs resulted in their inability to accomplish the survey during the winter of 1998-1999. As a result, the project Steering Committee researched additional research facilities outside UND to perform future surveys. In February 2000, the ATWIS Steering Committee requested Western Transportation Institute (WTI), Montana State University to perform a traveler survey only during the June to August 2000 timeframe.

The WTI survey was distributed to 3500 randomly chosen individuals living in North and South Dakota (Cuelho, 2000). It was sent to each individual via US mail on July 24, 2000. Participants were asked to respond to the survey by August 10, 2000. A total of 1128 surveys were completed and returned and included in the analysis.

The specific objectives of the survey were to assess system availability, system accuracy and system effectiveness. The various sections of the survey solicited the following types of information:

1. basic travel characteristics;
2. travel information needs;
3. amount and/or likelihood to use #SAFE;
4. #SAFE use;
5. qualitative assessment of #SAFE system;
6. willingness to pay; and,
7. demographic information.

Two types of questions were used throughout the survey: multiple choice questions and likert scale questions. Multiple choice questions contained between 4 and 10 responses. Likert scale questions allowed survey respondents to select one of three values they felt best represented their behavior or opinion regarding a particular topic. The ordinal nature of the scale allowed conclusions to be drawn on a relative basis only; differences between response values cannot be quantified. This is because each respondent's assessment of the intervals between the three responses will vary. To analyze the likert responses, numerical values were assigned to each of the three responses. The "VERY" response was assigned 3, the "SOMEWHAT" response was assigned 2 and the "NOT VERY" response was assigned a 1. Mean values are based on these numerical allocations. This was true of all of the likert based responses used in this survey.

In general, results from specific questions were qualitative and intended to make general improvements and modifications to the #SAFE system.

Survey administration was designed to target cellular telephone owners in North and South Dakota. A simple random sample of 3500 cellular users within North and South Dakota was purchased from USWest Dex (now Qwest) Data Products Group. The list of individuals was geographically diverse across the two-state region. From the 3500 surveys sent, 1128 were returned, resulting in a response rate of 32.2%. To increase the response rate, an incentive of $100 free Conoco gasoline was offered to five of those who responded. Once the surveys were mailed, no attempt was made to encourage those that did not respond to the survey to do so. The response rate was sufficient to conduct a valid statistical analysis.

The responses to the #SAFE survey were analyzed using various summary statistics, including percentages, frequencies and chi-square values. Results were used to determine user assessment of the system, traveler information needs and willingness to pay for use of the system. Differences in responses were investigated between respondents in selected demographic categories.

Respondents had the option of not responding to any question on the survey. Percentages were based on total responses obtained for each question, as opposed to the total number of survey respondents, thereby eliminating the need for an "unknown" or " no response" category for each question. Also, if more than one option was selected for questions requiring only a single response, all responses to that particular question were omitted from the statistical analysis. This was done to avoid biasing the results by choosing which option among several selected by the respondent was to be included. Failure to comply with written directions also resulted in omission of that particular response from the data analysis.

Approximately 15% of the respondents indicated that they used the #SAFE system. Allowing for bias by those who are excessive users of the system (results in a means use of 29.6 times per year), the mean use of the system by users is 13.6 times per year. Interestingly, nearly as many respondents indicated that they use the system both before they begin their trip and while on the road. This was an unexpected benefit as the initial goal was to provide en-route traveler information. And since there was not a published land-line to #SAFE, users were using their cellular phones to call the system from home.

One question was designed to collect qualitative data regarding #SAFE system availability. This was deemed an important question since system use is often related to its availability. Eighty-six percent of the respondents answered the question with a likert mean value of 2.47 or a positive indication that the system had sufficient availability to satisfy the users' needs.

Not too surprising was the fact that radio (89.2%) and television (78.4%) dominated as the sources travelers use most for road conditions or weather information. Given the relative obscurity of #SAFE, the 7.6% response was considered favorable, but below where future levels should be. And although not a surprise entirely, 52.2% of respondents indicated that they rely upon their own observations of existing conditions when traveling.

The important traveler information used for determining a change in travel plans were not a surprise with road and weather conditions being the most meaningful for the travelers. This underscored the premise of #SAFE. Further, the dominance of use during winter over other seasons and the influence of snow storms and blizzards on travel decisions further substantiated the purpose of developing #SAFE.

Important elements for the evaluation goal were the questions related to timeliness and accuracy of the information and the easy of understanding the information provided. In all three of these areas #SAFE did quite well with likert response of 2.31 for each of the timeliness and accuracy questions and 2.66 for the easy of use. However, most significant was the endorsement by the respondents of the usefulness of the information. This question gave the #SAFE system a likert value of 2.69 and a value of 2.39 was given to the impact the information has on altering their travel plans.

The one question that resulted in altering the state perspective on #SAFE pertained to the willingness of the traveler to pay for the information provided over 56% of the respondents indicated the information should be free with only 34% indicating they would be willing to pay for such information as was presently being provided. And of those willing to pay almost all indicated that the cost of the information should be less than $0.25

VII.1.4. Evaluation Goal Four

Goal: Demonstrate the feasibility of providing weather forecasting specifically for winter maintenance operations.

Methodology: Independent evaluator will perform annual customer market surveys across the two-state region.

Results:

During the early activities of ATWIS the North Dakota and South Dakota DOTs began to expand their vision of how the ATWIS research and #SAFE technologies could benefit their agencies. This resulted in a program modification to pursue potential improvement in supporting winter maintenance operations with improved surface transportation weather services. As it became a significant portion of the project, an evaluation goal was added to assess the feasibility of providing such specialized support for winter maintenance operations. The UND Bureau of Governmental Affairs as part of their independent evaluation responsibilities conducted surveys during the spring of 1997 and the winter of 1997-1998 of maintenance operators across both states. In 1999 WTI assumed the Bureau's responsibilities and the first maintenance operators' survey took place during the winter driving season 2000-2001.

The findings of the surveys corroborated the realities associated with increased interactions the ATWIS staff was experiencing during routine winter road weather forecasting. The findings of the UND and WTI surveys were:

- Transportation Department maintenance crew supervisors were almost all daily consumers of weather information following the change of objectives in the project.

- Almost all used the daily weather forecasts, most used the forecasts in their planning activities, and they rated the forecasts as accurate.
- A majority (75%) said they had altered their assignment of personnel as a result of the daily forecast.

These results were used as the ATWIS program came to a close to foster a new research endeavor at the UND RWIC associated with improving the road weather forecasting support to winter maintenance and integrating this weather information as part of a maintenance decision support system.

VIII. INTERNAL STATISTICAL REVIEW OF USAGE

Besides the independent evaluation of ATWIS activities, a self evaluation was performed to determine the usage of the #SAFE traveler information system. This involved collection of daily usage statistics over the period of contract performance. These statistics are provided below beginning with Figure 21 depicting the monthly data calls received by the system and Figure 22 depicting the data transactions handled per month of #SAFE operations. The difference between the data calls and data transactions come from the multiple data requests that can be requested during a single call. The fact that there are times of significant differences between these two is an indication that travelers are likely requesting additional information to support extended travel planning activities.

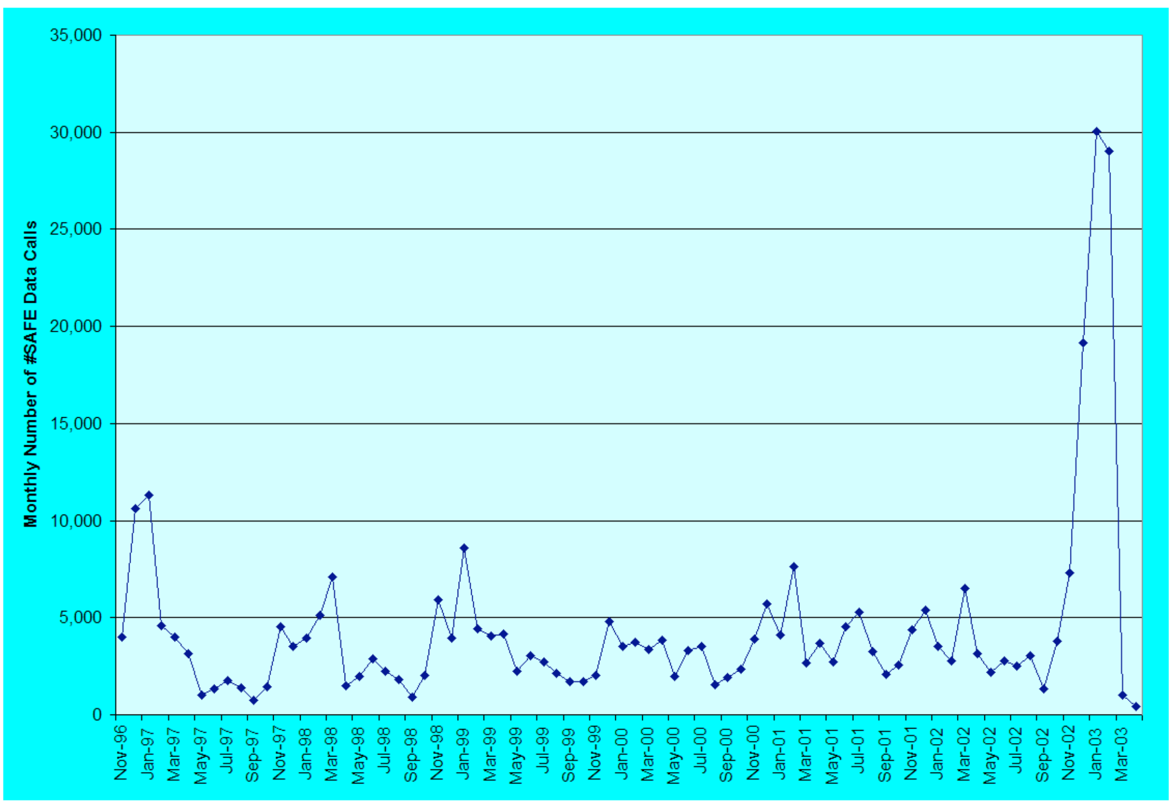

Figure 21. The summary of #SAFE monthly data calls between
November 1996 and April 2003.

The interpretation of the use of #SAFE clearly indicates a desire for information during travel across an entire state or even multi-state region. As describe earlier with the independent evaluation of #SAFE usage, it can be seen each year that a rapid increases occurs every November with the onset of winter driving conditions. The overall volume increase each year is also representative of the increase routes supported during the first few years of operations. While #SAFE had virtually no mass media advertising for the first four years, the immediate jump in usage that occurred the month the system came on-line is another clear indication of the acceptance of this service by the traveling public.

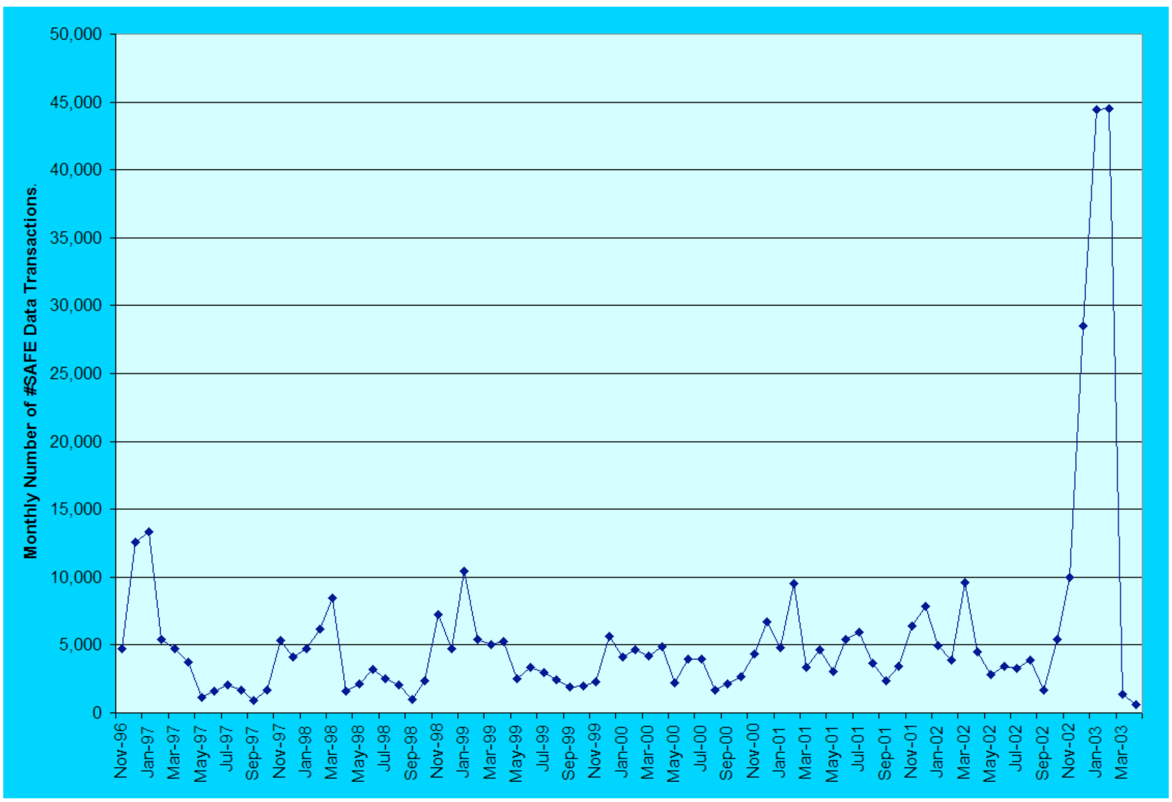

Figure 22. The summary of #SAFE monthly data transactions between November 1996 and April 2003.

While the figures 21 and 22 confirm #SAFE popularity was primarily during the winter months, notice must be taken of the increased daily usage during the summer as the system progressed. Annually, September and October are the low use month. The important factors in these statistics indicate traveler information is still very important during the summer as well as the winter.

An analysis of individual call patterns indicated that the majority of callers requested information for the travel corridor directly ahead of their current location. However, 14% of all callers also requested information for corridors many miles ahead as well. Of this 14%, 11% requested two reports, while 3% of the callers requested multiple reports, in some case across the state for their entire travel route.

As demonstrated by the hourly usage data in Figure 23, there has never been a day during the year or an hour during the day someone has not accessed #SAFE traveler information.

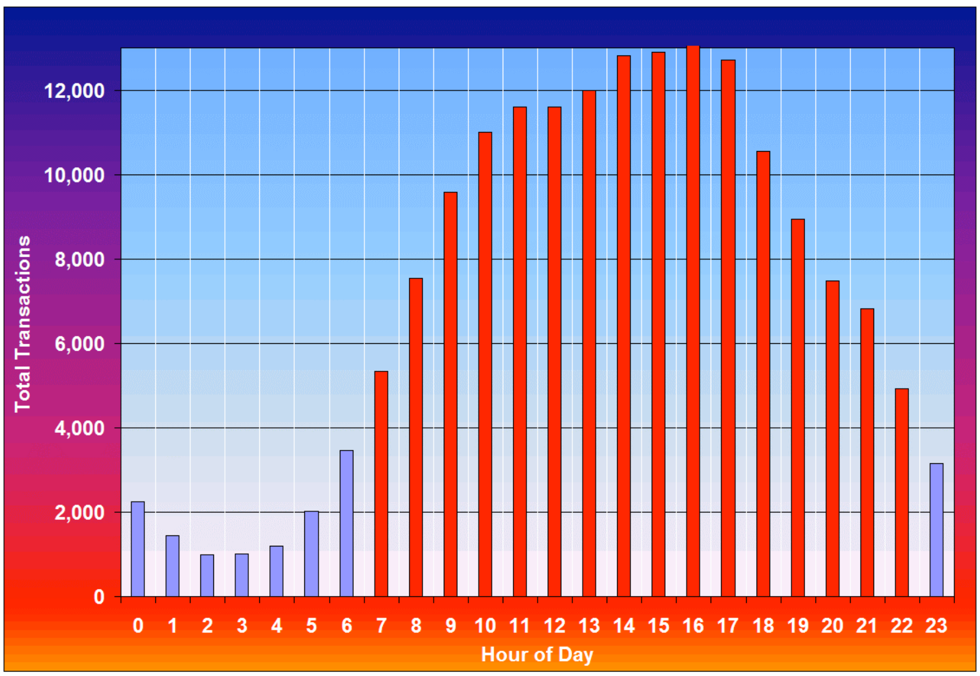

Figure 23. The distribution of calls during a 24-hour period for a representative year of #SAFE operational demonstration.

IX. Summary and Conclusion

The Advanced Transportation Weather Information System (ATWIS) was a pioneering endeavor that opened the technological doorway for present day advances in traveler safety and mobility. The present national 511 system that continues to expand across the nation owes its very beginning in rural areas to ATWIS and the #SAFE technologies that resulted. The ATWIS research was the first major road weather research to occur on a university and the benefits of the data assimilation and mesoscale weather prediction methodologies that it introduced into road weather forecasting systems now in practice has revolutionized the present practice of surface transportation weather services.

As an innovative concept ATWIS utilized the concept of ITS Integration to bring together disparate data systems in such a manner that not only en-route travelers could better plan their travel, but the level of awareness within state departments of transportation to available surface transportation weather resources was heightened to new levels. Following a Congressional mandate to complete a successful technology transfer into a sustainable operational system, ATWIS was able to complete this task through a successful public-private partnership. This partnership also raised the level of expectations from the surface transportation weather services private sector community.

But the efforts would have been for naught without the guidance of the ATWIS Steering Committee who provided the insight and leadership from both the transportation and meteorological communities to forge a bold path to follow. This cross pollination between the transportation and weather communities has resulted in new research initiatives that have built upon the results of ATWIS and #SAFE. The end result of this is the birth of a new meteorological sub-discipline, the surface transportation meteorologist that will continue the progress that ATWIS has just started.

In retrospect, the period of ATWIS was just a beginning that was inevitable to occur. In summary, the amount of knowledge gained and the new territory opened from ATWIS has been a monumental and unprecedented accomplishment in the road weather community.

X. References

Cluett, C. and F. Kitchener, 2004: “National Evaluation of Selected FY 2000 Earmarked ITS Integration Program Projects: Grand Forks, North Dakota”, Federal Highway Administration, DTFH61-96-C-00077, 43 pages.

Cuelho, E., 2000: “#SAFE Evaluation: Interim Report”, Western Transportation Institute, Montana State University, 26 pages.

Gannatsio, N.A., 1998: “Interim Report: Advanced Transportation Weather Information System”, Bureau of Governmental Affairs, University of North Dakota, 11 pages.

U.S. Department of Transportation
400 7th Street, S.W. (HOIT)
Washington, DC 20590
Toll-Free "Help Line" 8666-367-7487
www.its.gov

EDL Document No.: XXXXX

Publication No.: XXXXX-XXX-XX-XXX

HOIT/11-05 (2M)