Best Practices for Road Weather Management

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Table of Contents

Section Page

Appendices

Introduction

Weather threatens surface transportation nationwide and impacts roadway mobility, safety, and productivity. There is a perception that transportation managers can do little about weather. However, three types of mitigation measures—control, treatment, and advisory strategies—may be employed in response to environmental threats and impacts. For example, strategies may include road weather and traffic surveillance to monitor threats to transportation system performance, arterial and freeway management to modify roadway capacity, as well as dissemination of advisory information to influence traveler decisions and driver behavior. These management practices are employed in response to various weather threats including fog, high winds, snow, rain, ice, flooding, tornadoes, hurricanes, and avalanches.

This report contains case studies of systems that improve roadway operations under inclement weather conditions. Each case study demonstrates the entire information thread, from environmental information to system performance information. This information thread begins with the observation and prediction of weather, road surface, traffic, and other environmental conditions to identify threats to system performance. Based upon credible threat information traffic, emergency, and maintenance managers employ mitigation strategies that improve transportation outcomes. The appendix includes an acronym list, online resources, and a listing of road weather publications.

Each case study has six sections including a general description of the system or application, system components, operational procedures to cope with weather effects, resulting transportation outcomes, and implementation issues. Contact information and references are also provided for each case study.

California DOT Motorist Warning System

Freeways in the Stockton-Manteca area of San Joaquin County, California are prone to low visibility conditions. Visibility is reduced by wind-blown dust in the summer and dense localized fog in the winter. In the past low visibility has contributed to numerous chain-reaction collisions in the San Joaquin Valley. To improve roadway safety on southbound Interstate 5 and westbound State Route 120, the California Department of Transportation (DOT)—also known as Caltrans—implemented an automated system to warn motorists of driving hazards.

System Components: Traffic and weather data are collected from 36 vehicle detection sites and nine Environmental Sensor Stations (ESS) deployed along the freeways. Detection sites are comprised of paired inductive loop detectors and Caltrans Type 170 controllers, which run software with speed measurement algorithms. Each ESS includes a rain gauge, a forward-scatter visibility sensor, wind speed and direction sensors, a relative humidity sensor, a thermometer, a barometer, and a processing unit. Traffic and environmental data are transmitted from the field to a networked computer system in the Stockton Traffic Management Center (TMC) via dedicated, leased telephone lines. The central computer system automatically displays advisories on nine roadside Dynamic Message Signs (DMS).

ESS

System Operations: Three central computers control operation of the motorist warning system. A meteorological monitoring computer records and displays ESS data. A traffic monitoring computer uses a program developed by Caltrans operations staff to record, process, and display traffic volume and speed data. Through interfaces with the monitoring computers, a DMS control computer accesses environmental and average speed data to assess driving conditions. Based upon established thresholds for vehicle speed, visibility distance, and wind speed; proprietary control software automatically selects and displays warnings on DMS as shown in the table below. TMC operators also have the capability to manually override messages selected by the system.

California DOT Motorist Warning System Messages

Conditions	Displayed Message
Average speed between 11 and 35 mph (56.3 kph)	"SLOW TRAFFIC AHEAD"
Average speed less than 11 mph (17.7 kph)	"STOPPED TRAFFIC AHEAD"
Visibility distance between 200 and 500 feet (152.4 meters)	"FOGGY CONDITIONS AHEAD"
Visibility distance less than 200 feet (61.0 meters)	"DENSE FOG AHEAD"
Wind speed greater than 35 mph	"HIGH WIND WARNING"

Transportation Outcome: The motorist warning system has improved highway safety by significantly reducing the frequency of low-visibility accidents. Nineteen fog-related crashes occurred in the four-year period before the system was deployed. Since the system was activated in November 1996, there have been no fog-related crashes.

Implementation Issues: Designers considered local conditions and potential safety benefits to assess the feasibility of a warning system. Limited sight distances, converging traffic patterns, and frequent low visibility events factored into the decision to deploy a motorist warning system on selected freeways. These factors also guided development of system requirements. The system had to have the capability to continuously and automatically collect, process, and display information. System designers examined historical accident data to establish a baseline for evaluation of the motorist warning system.

System components include commercially available products as well as hardware and software developed by Caltrans operations staff. The meteorological monitoring system was procured as a turnkey solution. The ESS manufacturer installed field devices, the monitoring computer, and proprietary processing software. Caltrans personnel designed and installed the traffic monitoring and DMS control components using standardized and commercial off-the-shelf products to minimize procurement costs and deployment time. Because display technologies had to be visible in adverse conditions, incandescent DMS were selected based upon their readability in low visibility conditions. After system elements were procured, installed, and calibrated operational procedures were developed, maintenance schedules and contracts were arranged, and traffic operations personnel were trained.

Future system expansion was taken into account by designers. Anticipated enhancements include the integration of the monitoring and control computers into a single workstation, incorporation of a Closed Circuit Television surveillance system for visual verification of roadway conditions, and inclusion of a Highway Advisory Radio system to supplement visual warning messages. An interface to the California Highway Patrol information system is also expected.

Contact(s):
- Clint Gregory, Caltrans District 10, Electrical Systems Branch Chief, 209-948-7449, clint_gregory@dot.ca.gov.

Reference(s):

- MacCarley, A., "Evaluation of Caltrans District 10 Automated Warning System: Year Two Progress Report," California PATH Research Report UCB-ITS-PRR-99-28, August 1999, http://www.path.berkeley.edu/PATH/Publications/PDF/PRR/99/PRR-99-28.pdf.
- Spradling, R., "Operation Fog," Caltrans District 10 Press Release, October 2001, http://www.dot.ca.gov/dist10/pr01.htm.
- URS BRW, "San Joaquin Valley Intelligent Transportation System (ITS) Strategic Deployment Plan: Working Paper #1," January 2001 http://www.mcag.cog.ca.us/sjvits/pages/..%5CPDF%20Files%5CWorking%20Paper%20No1.pdf.

Keywords: fog, dust, wind, visibility, motorist warning system, freeway management, traffic management, advisory strategy, traveler information, vehicle detection, environmental sensor station (ESS), dynamic message signs (DMS), safety

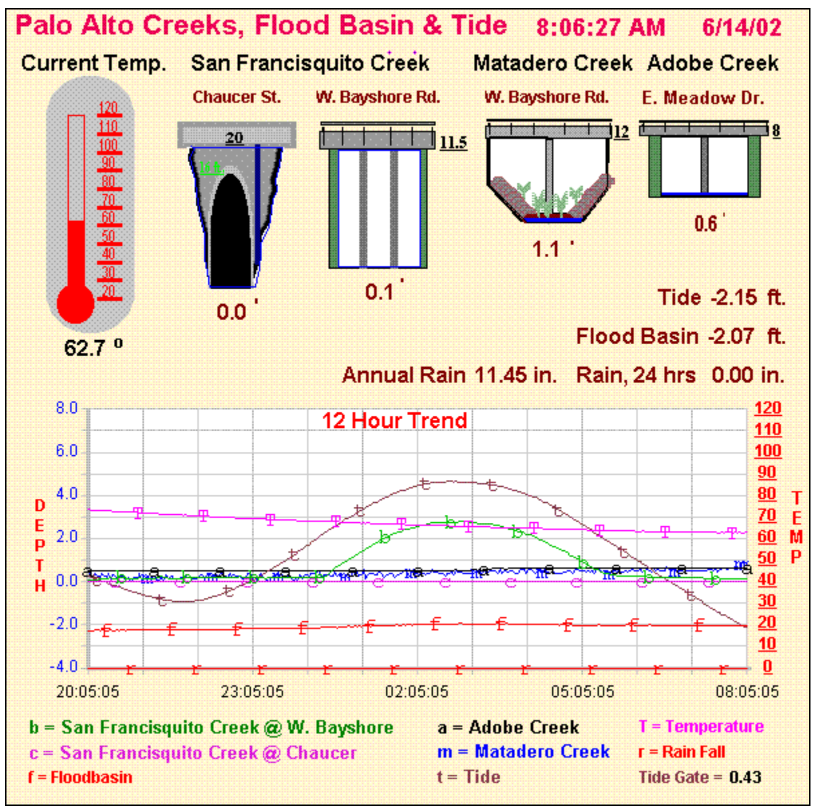
City of Palo Alto, California Flood Warning System

In February 1998 several days of heavy rainfall caused the San Francisquito creek to overflow its banks flooding the City of Palo Alto, California. City residents and emergency managers had no advanced warning of the flood. This event prompted the City to develop a flood warning system. This web-based system has become an integral part of the City's emergency management operations. When flood conditions exist, emergency managers utilize automated surveillance techniques to supply information to the public.

System Components: Water level sensors, a rain gauge, flood basin detectors, tide monitors, and a Closed Circuit Television camera are used to assess field conditions. Ultrasonic sensors were installed at five bridge locations to detect high water or flood conditions. The ultrasonic water level sensors use acoustics or sound waves to measure the distance from a transducer to the water surface. Water level readings are transmitted to the water, gas, and storm drain Supervisory Control and Data Acquisition (SCADA) system via the City's telephone and radio communication networks. A Digital Subscriber Line transmits still video images from one bridge site to the Emergency Operations Center (EOC).

System Operations: Real-time and historical water level data and video images are posted on the City's "Creek Level Monitor" web site for viewing at the EOC and by Palo Alto residents. Current water level, 12-hour water level trend, 24-hour rainfall, annual rainfall, current temperature, and tidal data are updated every minute on the SCADA system computer and posted on the server for website updates every three minutes.

Emergency managers access this information to plan response actions and to alert residents. In the event of a flood threat, an automatic telephone warning system at the EOC dials all City residents and businesses in threatened areas to advise of potential flood conditions.



"Creek Level Monitor" Web Site
(*www.city.palo-alto.ca.us/earlywarning*)

Transportation Outcome: Prior to installation of the flood warning system, emergency management personnel traveled to bridge locations to visually monitor the storm drain system and physically check water levels. Drain system status and water level readings were radioed to the EOC every 20 minutes. By eliminating the need for field measurements, the monitoring system has enhanced the productivity of City staff and provided timely access to traveler information to improve public safety. City residents may utilize information to make travel and safety decisions.

Implementation Issues: The warning system project was initiated due to resident complaints following the 1998 flood. The Public Works Operations department conducted a study of the City's bridge locations and wireline communication systems, assessed sensor technologies, and deduced that water level sensors could be deployed and integrated with the existing SCADA system. Non-intrusive sensors were selected over other technologies (e.g., pressure transmitters, bubblers, floats) due to concerns about floating or submerged debris that could damage equipment placed in the creeks.

The original intent of the system was to furnish emergency managers with precipitation and hydrologic data, which would serve as decision support for providing information to the public. After determining hardware, software, and interface requirements system designers decided to add the web-based information dissemination feature to better serve city residents.

Contact(s):
- John Ballard; City of Palo Alto, California; Public Works Operations; 650-496-5935.

References:
- Kulisch, E., "System Monitors Flood-prone Creeks", www.civic.com/civic/articles/2001/0122/web-flood-01-26-01.asp
- City of Palo Alto, "Creek Level Monitor Website: How Do We Do It?" http://www.city.palo-alto.ca.us/earlywarning/how.html.

Keywords: rain, flooding, flood warning system, emergency management, traveler information, advisory strategy, bridge, remote sensing, closed circuit television (CCTV), internet/website, safety, productivity

City of Aurora, Colorado Maintenance Vehicle Management System

In 1998 the City of Aurora, Colorado deployed a system to monitor the operation of maintenance vehicles, including snowplows and street sweepers. The system has facilitated real-time communication between maintenance managers and vehicle drivers, enhanced productivity, and improved public relations.

System Components: The maintenance vehicle management system is comprised of in-vehicle devices, central control systems, and a wireless communication system. Approximately 30 snowplows are equipped with integrated display, messaging, and communication devices. With these in-vehicle devices, text messages can be entered with a keypad, displayed to drivers, and transmitted between maintenance vehicles and central computers via a Cellular Digital Packet Data modem. Each in-vehicle device also includes an interface to vehicle systems and a Global Positioning System receiver, which is used to automatically track equipment status and vehicle location from control computers in two central facilities.

In-Vehicle Device

System Operations: Central control systems allow maintenance managers to transmit pre-programmed or customized messages to a single plow, a selected group of plows, or all snowplows. Managers can monitor road treatment activities with a map display of snowplow locations to assess which routes have been serviced, determine when a plow is off of its designated route, and plan route diversions as needed. The status of vehicle systems may also be monitored to ascertain whether plow blades are up or down and to determine when treatment materials are being dispensed. The management system is utilized for treatment strategy planning, real-time operations monitoring, and post-event analysis.

Transportation Outcome: By using the management system to track maintenance vehicles, managers have minimized treatment costs and improved productivity by nearly 15 percent. Additionally, managers can easily access the system and provide accurate information to citizens who call the City to inquire about plowing of a particular street.

Implementation Issues: The City contracted with a private vendor to furnish and install in-vehicle and central components of the management system. System deployment was expedited by involving the City's information systems staff in planning and design, and by hiring a local system integrator to resolve compatibility issues related to the various component and communications providers.

Contact(s):

- Lynne Center; City of Aurora, Colorado Public Works Department, 303-326-8200, lcenter@ci.aurora.co.us.

Reference(s):

- Beneski, B., "Orbital's Satellite-Based Vehicle Tracking System Selected by Aurora, Colorado," Orbital Sciences Corporation Press Release, July 1998, http://www.orbital.com/Template.php?Section=News&NavMenuID=32&template=PressReleaseDisplay.php&PressReleaseID=159.

Keywords: winter storm, snow, ice, maintenance vehicle management system, winter maintenance, treatment strategy, advisory strategy, maintenance vehicle, productivity

Florida DOT Motorist Warning System

The tropical climate in south Florida typically causes heavy rainfall in the afternoon. A Florida Department of Transportation (DOT) study of the Florida Turnpike/Interstate 595 interchange found that 69 percent of crashes on a two-lane, exit ramp occurred when the pavement was wet and that only 44 percent of these wet-pavement crashes happened when it was raining. The wet-pavement accident rate on this ramp was three times higher than the national average and nearly four times greater than the statewide average. To demonstrate how advanced warning of the safe travel speed under wet pavement conditions can reduce accident risk, the DOT installed an automated motorist warning system on the ramp, which has a sharp curve and an upgrade.

System Components: A sensor embedded in the road surface was used to monitor pavement condition (i.e., dry or wet). On a pole adjacent to the ramp, a microwave vehicle detector was installed to record traffic volume and vehicle speed, and a precipitation sensor was mounted to verify rainfall events. A pole-mounted enclosure housed a remote processing unit (RPU), which was hard-wired to flashing beacons atop static speed limit signs. A dedicated telephone line was also connected to the RPU to facilitate data retrieval from an Internet server in the turnpike operations center located in Pompano Beach.

Pavement Sensor

System Operations: The RPU collected, processed, and stored traffic and pavement data from the sensors. When pavement moisture was detected, the RPU activated the flashing beacons to alert motorists that speeds should not exceed the posted limit of 35 mph (56.3 kph).

Transportation Outcome: The warning system improved safety by reducing vehicle speeds and promoting more uniform traffic flow when the ramp was wet. In light rain conditions, the 85th percentile speed decreased by eight percent from 49 to 45 mph (78.8 to 72.4 kph). During heavy rain, there was a 20 percent decline in 85th percentile speed from 49 to 39 mph (78.8 to 62.7 kph). Speed variance was reduced from 6.7 to 5.7 mph (10.8 to 9.2 kph) in light rain and from 6.1 to 5.6 mph (9.8 to 9.0 kph) in heavy rain. Thus, speed variance decreased by eight to 15 percent, minimizing accident risk. Four crashes occurred during the first week of warning system activation. Three happened when the pavement was wet and one occurred during rainfall. After this initial week, there were no reported crashes the during nine-week evaluation period.

Implementation Issues: The DOT evaluated the geometry, road surface conditions, and accident history of the ramp, which had the highest travel speeds and the highest crash rate of all the ramps in the interchange. It was concluded that wet pavement and excessive travel speeds were the primary factors contributing to run-off-the-road crashes that occurred at the beginning of the sharp ramp curve. These conditions warranted the development and demonstration of a motorist warning system. The demonstration project was a joint effort of the Florida DOT, the University of South Florida, and a private vendor.

The DOT erected a 25-foot (7.6-meter) equipment mounting pole 8 feet (2.4 meters) from the edge of the travel lane, installed flashing beacons on two existing ramp signs, and arranged power and telephone service connections. The pole was installed approximately 180 feet (55 meters) in advance of the speed limit signs. The vendor furnished and installed field sensors, the RPU, and the Internet server. The pavement sensor was installed at the lowest elevation point of the ramp.

After installation, the project partners verified the accuracy and reliability of system components. Vehicle detector data accuracy was validated by comparing speed measurements with those from a hand-held radar gun. The private vendor calibrated the dry-wet threshold of the pavement sensor. Beacon activation by the RPU and field data downloading to the turnpike operations center were successfully tested. Through the server, the University retrieved pavement condition, speed, and volume data at one-minute intervals to evaluate system performance before and after activation.

Contact(s):

- Michael Pietrzyk, University of South Florida, Center for Urban Transportation Research (CUTR), 813-974-9815, pietrzyk@cutr.eng.usf.edu.

Reference(s):

- Pietrzyk, M., “Are Simplistic Weather-Related Motorist Warning Systems ‘All Wet’?”, University of South Florida, presented at Institute of Transportation Engineers (ITE) Annual Meeting, August 2000.
- Collins, J. and Pietrzyk, M., ”Wet and Wild: Developing and Evaluating an Automated Wet Pavement Motorist System,” Kimley-Horn and Associates, presented at the Transportation Research Board (TRB) Annual Meeting, January 2001.

Keywords: rain, pavement condition, pavement friction, motorist warning system, freeway management, traffic management, advisory strategy, pavement sensor, vehicle detection, speed, driver behavior, crashes, safety

City of Clearwater, Florida Weather-Related Signal Timing

The City of Clearwater, Florida operates a computerized traffic control system with 145 signals. City traffic managers have developed a unique rain preemption feature that modifies signal timing during rain events to clear traffic from Clearwater Beach, which is a prime destination for tourists visiting Orlando and Tampa Bay. Thunderstorms typically occur in the afternoon, causing significant sudden increases in traffic exiting the beach via the Memorial Causeway (i.e., State Route 60).

System Components: A rain gauge is mounted at a traffic signal near the beach. Vehicle detectors on the causeway are used to measure the length of traffic queues on inbound lanes. Traffic signal controllers are installed at City intersections. A twisted pair cable communication system connects the rain gauge, vehicle detectors, and controllers to a signal system computer at the City's Traffic Operations Center (TOC).

System Operations: When the rain gauge senses a predetermined rainfall amount, the signal system computer issues a preemption command to 14 downtown traffic signals along the Route 60 corridor. These signal controllers execute new timing plans with longer green times for inbound approaches. The computer selects the appropriate timing plan based upon traffic volumes. When the volume returns to normal levels, the central computer restores normal signal timing plans.

Transportation Outcome: By modifying traffic signal timing in response to rain events, the signal system computer prevents traffic congestion and enhances roadway mobility.

City of Clearwater Map

Implementation Issues: The City of Clearwater was one of the first jurisdictions to deploy an Urban Traffic Control System (UTCS) with the assistance of federal funds. The UTCS included preemption features for drawbridges and railroad crossings. City personnel assessed localized conditions, observed driver behavior during thunderstorms, and determined that a similar feature could be implemented for rain events affecting Clearwater Beach. The City's signal technicians installed a commercially available rain gauge at an intersection that is adjacent to a parking garage used by beach visitors. The signal system engineer modified existing UTCS preemption algorithms to alter signal timing based upon rainfall and traffic volume data.

In 2003 the City's central UTCS will be upgraded from a mainframe computer system to a PC-based system to support adaptive signal control as part of a county-wide, federally-funded Congestion Mitigation and Air Quality project. Closed Circuit Television cameras and Dynamic Message Signs will also be installed on the City's primary corridors. Pinellas County will operate a TOC and utilize a Wide Area Network to facilitate data sharing between the county TOC and TOCs located in the cities of Clearwater and St. Petersburg.

Contact(s):

- Paul Bertels; City of Clearwater, Traffic Operations Manager; 727-562-4794; pbertels@clearwater-fl.com.
- Glen Weaver; City of Clearwater, Signal System Engineer; 727-562-4794.

Reference(s):

- City of Clearwater, Florida Web Site, http://www.clearwater-fl.com/.

Keywords: rain, weather-related signal timing, arterial management, traffic management, traffic control, control strategy, vehicle detection, volume, mobility

Idaho DOT Anti-Icing/Deicing Operations

In 1996 maintenance managers with the Idaho Department of Transportation (DOT) began an anti-icing program on a 29-mile (47-kilometer) section of US Route 12. This highway segment is located in a deep canyon and is highly prone to snowfall and pavement frost (i.e., black ice) due to sharp curves and shaded areas. An anti-icing chemical is applied to road surfaces as an alternative to spreading high quantities of abrasives. Abrasives are thrown to the roadside by passing vehicles and only improve roadway traction temporarily.

System Components: Winter maintenance managers installed chemical storage tanks and modified maintenance vehicles for use in anti-icing operations. A chemical storage facility with two 6,900-gallon (26,117-liter) storage tanks and an electric pump for chemical circulation and truck loading was located in the Orofino maintenance yard. Trucks with 1,000-gallon (3,785-liter) and 1,500-gallon (5,678-liter) tanks were equipped with spray controls to dispense liquid magnesium chloride.

Maintenance Vehicles and Chemical Storage Tanks

System Operations: Maintenance managers utilize the Internet to access weather forecast data and identify threatening winter storms or frost events. When an impending threat is predicted, maintenance vehicles are deployed to spray small amounts of the anti-icing chemical on road surfaces before snowfall begins or frost forms. Chemical application rates vary from ten to 50 gallons (37.9 to 189.3 liters) per lane mile, depending on the nature and magnitude of the threat. Maintenance crews regularly check four “indicator areas” along the highway to determine when frost on shoulder lanes begins to migrate into travel lanes. The status of these areas indicates that the road should be retreated to ensure that chemical concentrations are high enough to prevent freezing.

Transportation Outcome: To assess the effectiveness of anti-icing operations, winter road maintenance activities were analyzed for five years prior to the anti-icing program and for three years after implementation. Annual averages of abrasive quantities, labor hours, and winter crashes are shown in the following table.

Idaho DOT Winter Maintenance Annual Averages

	1992 to 1997 (Without Anti-Icing)	1997 to 2000 (With Anti-Icing)	Percent Reduction
Abrasive Quantities	1,929 cubic yards (1,475 cubic meters)	323 cubic yards (247 cubic meters)	83%
Labor Hours	650	248	62%
Number of Crashes	16.2	2.7	83%

Mobility, productivity, and safety enhancements resulted from the anti-icing treatment strategy. Mobility was improved, as a single application of magnesium chloride was typically effective at improving traction for three to seven days—depending on precipitation, pavement temperature, and humidity. Faster clearing of snow and ice reduced operation costs and enhanced productivity. Safety improvements were realized by reducing the frequency of wintertime crashes.

Implementation Issues: Maintenance managers selected the US Route 12 segment for their anti-icing pilot program due to the high crash rate and high maintenance costs. Relatively mild winter temperatures, hazardous winter road conditions, and moderate traffic volumes also made this roadway a good candidate for anti-icing operations.

Other Idaho DOT maintenance districts had successful anti-icing programs. By consulting other districts and assessing existing vehicles, managers developed treatment equipment requirements. Trucks, previously used to spray weed-killing and other chemicals, were modified to dispense liquid magnesium chloride. After configuring the treatment equipment, crews were trained in all aspects of anti-icing procedures. They learned about various anti-icing chemicals and their properties, chemical application criteria and rates, equipment operation, and progress tracking. As a result of the successful pilot program, anti-icing was expanded to other highways in District 2 and throughout the state.

Contact(s):
- Bryon Breen, Assistant Maintenance Engineer, 208-334-8417, bbreen@itd.state.id.us.

Reference(s):

- Breen, B. D., "Anti Icing Success Fuels Expansion of the Program in Idaho," Idaho Transportation Department, March 2001.

Keywords: snow, ice, winter storm, anti-icing/deicing operations, freeway management, winter maintenance, treatment strategy, internet/website, forecasts, weather information, maintenance vehicle, chemicals, crashes, mobility, productivity, safety

Idaho DOT Motorist Warning System

The Idaho Department of Transportation (DOT) installed a motorist warning system on a 100-mile (161-kilometer) section of Interstate 84 in southeast Idaho and northwest Utah. This road segment was highly prone to multi-vehicle crashes when blowing snow or dust reduced visibility. From 1988 to 1993, poor visibility contributed to 18 major crashes involving 91 vehicles, 46 injuries, and nine fatalities. While the proportion of trucks on this rural freeway was 33 percent, the percentage of trucks in these crashes was 44 percent. Traffic managers display advisory messages to motorists to influence driver behavior under adverse conditions.

System Components: Road, weather, and traffic condition data are collected by sensor systems and transmitted to a central computer. Environmental Sensor Stations (ESS) detect pavement condition (i.e., dry, wet, or snow-covered), wind speed and direction, precipitation type and rate, air temperature, and relative humidity. Sensors with forward-scatter detection technology measure visibility distance. Inductive loop vehicle detectors record vehicle length (i.e., passenger car or truck), vehicle speed, and travel lane. A Closed Circuit Television (CCTV) surveillance system is also utilized to visually confirm roadway conditions. A CCTV camera is pointed at five roadside target signs equipped with flashing lights. The target signs were positioned along the interstate at known distances from the camera (i.e., 250, 500, 850, 1200, and 1500 feet or 76, 152, 259, 366, and 457 meters). Notifications of adverse conditions are posted on four roadside Dynamic Message Signs (DMS).

System Operations: The central computer records sensor readings every five minutes. When field sensor data indicates that visibility has fallen below a predetermined threshold or that driving conditions are deteriorating, the computer in the Traffic Control Center (TCC) alerts traffic managers. System operators then confirm visibility levels by viewing video images of target signs. Based upon prevailing road conditions, traffic managers decide which messages to display and manually activate DMS.

Transportation Outcome: A system evaluation conducted from 1993 to 2000 compared traffic speeds with advisories to speeds without warnings. When traffic managers displayed condition data during high winds (i.e., over 20 mph or 32.2 kph), average speed variance was reduced and average vehicle speed decreased by 23 percent from 54.8 to 42.3 mph (88.1 to 68.0 kph). When high winds occurred simultaneously with moderate to heavy precipitation, average speeds were 12 percent lower. Under these conditions, mean speeds were 47.0 mph (75.6 kph) without advisory information and 41.2 mph (66.2 kph) with warning messages. A 35-percent decline in average vehicle speed occurred when the pavement was snow-covered, wind speeds were high, and warnings were displayed. Average speeds fell from 54.7 to 35.4 mph (87.9 to 56.9 kph). Advisory information presented by traffic managers prompted changes in driver behavior, improving safety and mobility.

Implementation Issues: After determining that a motorist warning system was warranted based upon local traffic patterns, weather conditions, and accident history; traffic managers assessed three different types of visibility sensors. Tests were conducted to determine the accuracy of visibility measurements in a rural setting and to select the most reliable and cost effective sensor. After field sensors were selected, their locations were determined and power and communications systems were designed. To ensure that weather and traffic data was collected at the same location, ESS were installed within a few hundred feet of the vehicle detection sites.

System integration issues arose due to the various field data types and formats, hardware and software incompatibility, as well as communication system and power system failures. For example, the software used to control two of the DMS was not compatible with the central computer. Because leased telephone lines in this rural area were not reliable for transmission of sensor data at the desired frequency, a dedicated telephone cable was installed from the system location to the TCC. Power supply reliability was also a concern. Numerous power outages, shortages, and surges damaged field and central components. Uninterruptible power supplies were installed to address these problems.

Contact(s):

- Bob Koeberlein, Idaho Transportation Department, ITS Program Manager, 208-334-8487, rkoeberl@itd.state.id.us.
- Bruce Christensen, Idaho Transportation Department, District 4 Traffic Engineer, 208-886-7860, bchriste@itd.state.id.us.

Reference(s):

- Kyte, M., et al, “Idaho Storm Warning System Operational Test - Final Report,” prepared for the Idaho Transportation Department, ITD No. IVH9316 (601), December 2000, http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/@cc01!.pdf.
- Booz-Allen & Hamilton, “Intelligent Transportation Systems Compendium of Field Operational Test Executive Summaries,” FHWA Turner-Fairbank Highway Research Center, http://www.its.dot.gov/new/optest.pdf.

Keywords: visibility, dust, wind, precipitation, snow, motorist warning system, freeway management, traffic management, advisory strategy, traveler information, vehicle detection, environmental sensor station (ESS), dynamic message signs (DMS), closed circuit television (CCTV), driver behavior, speed, safety, mobility

Minnesota DOT Access Restriction

Since 1996 several Minnesota Department of Transportation (DOT) maintenance districts have worked with the Minnesota State Patrol and county sheriffs to direct traffic off of freeways and to restrict freeway access at ramps when winter storms create unsafe travel conditions. After maintenance vehicles have cleared snow and ice, freeways are reopened to traffic.

System Components: Two types of gates are used to restrict freeway access. One maintenance district has installed gate arms that are positioned on the side of the road and swing into place when needed. These arms have amber lights. Other districts deployed upright gate arms, with red lights, that are lowered into position. Static fold-down warning signs are located in advance of gates to notify motorists of freeway closures.

System Operations: Traffic and maintenance managers consider several variables to identify threats to highway operations. Weather parameters include winter storm duration and severity (i.e., snowfall rate), and visibility. Pavement condition, time of day, day of the week, seasonal travel patterns, and the capacity of towns to accommodate diverted motorists are transportation system factors. Threat information is used to determine closure locations and times.

When a threat is identified traffic and emergency management personnel execute a systematic, coordinated plan to divert traffic off of freeways with mainline gates and prohibit freeway access using ramp gates. DOT personnel travel to gate locations to open warning signs and activate gate arm lights. Gate arms are then positioned in travel lanes to alert drivers that the freeway is closed. During closure and reopening activities, uniformed law enforcement personnel staff gate locations with patrol vehicles to prevent motorists from interfering with clearing operations.

Gate Arms and Warning Sign

Transportation Outcome(s): During a severe snowstorm on November 11, 1998 a 50-mile (80.4-kilometer) section of Interstate 90 was closed, while 59 miles (94.9 kilometers) of US Highway 75 remained open. Plows made four passes on Interstate 90 and ten passes on Highway 75 to clear the pavement of snow and ice. The freeways were reopened when the pavement was 95 percent clear. Because Highway 75 was open to traffic, significant snow compaction occurred on this roadway. Delay on Interstate 90 was minimized, as it was cleared four hours before Highway 75. As shown in the table below, over 24 dollars per lane mile were expended on Highway 75, while it cost less than 20 dollars per lane mile to clear Interstate 90.

Minnesota DOT Access Restriction and Maintenance Costs

	US Highway 75 (Open to Traffic)	Interstate 90 (Access Restricted)	Percent Difference
Number of Plow Passes	10	4	60%
Total Miles Plowed	590	200	66%
Labor Hours per lane mile	0.41	0.38	7%
Labor Costs per lane mile	$9.98	$9.08	9%
Material Costs per lane mile	$4.59	$4.50	2%
Equipment Costs per lane mile	$9.54	$6.14	36%
Total Costs per lane mile	**$24.11**	**$19.72**	**18%**

The DOT conducted a study of Interstate 90 closures in 1999. Analysis revealed that roughly 80 crashes per year were related to poor road conditions on the freeway. Study results also confirmed that access restriction operations enhanced mobility by reducing closure time and associated vehicle delay. Examination of this control strategy during a single storm event and over a six-month period indicated that productivity, mobility, and safety were improved.

Implementation Issues: The DOT contracted with a consulting firm to analyze the costs and benefits of deploying gate arms for access restriction. The consultant used historical operations and accident data to calculate benefits associated with reductions in travel time delay and crash frequency. After deciding to implement gate arms based upon the benefit/cost analysis, the DOT consulted agencies in North and South Dakota. An assessment of gates used in the Dakotas found that snowdrifts could block swinging gates necessitating shoveling before they could be positioned in the road. The upright gates also had disadvantages. In some cases, the pulley mechanism failed causing the gate arm to slam down unexpectedly. Individual maintenance districts selected the type of arm most appropriate for their operations. Ice and high winds occasionally interfered with the opening of warning signs.

The DOT plans to test remote operation of gates and Closed Circuit Television surveillance at one interchange. Remote monitoring and control via a secure web site will be tested during the 2002/2003 winter season.

Contact(s):
- Farideh Amiri, Minnesota DOT, ITS Project Manager, 651-296-8602, farideh.amiri@dot.state.mn.us.

Reference(s):

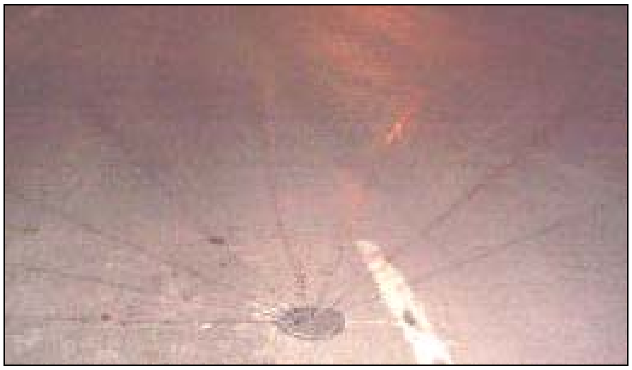
- Nookala, M., et al, “Rural Freeway Management During Snow Events - ITS Application,” presented at the 7th World Congress on Intelligent Transport Systems, November 2000.
- BRW, “Documentation and Assessment of Mn/DOT Gate Operations,” prepared for Minnesota DOT Office of Advanced Transportation Systems, October 1999, http://www.dot.state.mn.us/guidestar/pdf/gatereport.pdf.

Keywords: winter storm, snow, ice, access restriction, freeway management, treatment strategy, winter maintenance, control strategy, traffic control, law enforcement, advisory strategy, motorist warning system, institutional issues, gates, maintenance vehicle, safety, mobility, productivity

Minnesota DOT Anti-Icing/Deicing System

Several Minnesota Department of Transportation (DOT) districts have installed fixed maintenance systems on curved and super-elevated bridges that are prone to slippery pavement conditions. On Interstate 35 an automated anti-icing system was installed on a 1,950-foot (594-meter), eight-lane bridge near downtown Minneapolis. The bridge deck was susceptible to freezing due to moisture rising from the Mississippi River below. On average 25 winter crashes occurred on the bridge each year causing significant traffic congestion.

System Components: The automated anti-icing system is comprised of a small enclosure, storage tanks, a pump and delivery system, environmental sensors, four motorist warning signs with flashing beacons, and a control computer located in the district office. The enclosure houses the pump, a 3,100-gallon (11,734-liter) chemical storage tank, a 100-gallon (379-liter) water storage tank, and control mechanisms. Liquid potassium acetate is pumped through the delivery system to 38 valve bodies installed in the median barrier. The valves direct the anti-icing chemical to 76 spray nozzles. Sixty-eight nozzles are embedded in the bridge decks of both northbound and southbound lanes. These nozzles are installed in the center of travel lanes at a spacing of 55 feet (16.8 meters). Eight barrier-mounted nozzles are located at the north end of the bridge to spray approach and exit panels.



Spray Nozzle in Pavement

Two types of environmental sensors that are installed on the bridge. An Environmental Sensor Stations (ESS) is equipped with air and subsurface temperature sensors, pavement temperature and pavement condition sensors, as well as precipitation type and intensity sensors. The second sensor site includes only pavement temperature and condition sensors. These environmental sensors determine whether the pavement is wet or dry and whether the pavement temperature is low enough for surface moisture to freeze.

System Operations: The control computer continuously polls the environmental sensors to gather data used to predict or detect the presence of black ice or snow. When predetermined threshold values are met, the computer automatically activates flashing beacons on bridge approach ramps to alert motorists, checks the chemical delivery system for leaks, and initiates one of 13 spray programs. Each program activates different valves, in various spray sequences, at different spray frequencies based upon prevailing environmental conditions. An average spray cycle dispenses 34 gallons (128.7 liters) of potassium acetate (i.e., 12 gallons or 45.4 liters per lane mile) over ten minutes. Conventional treatment strategies (e.g., plowing, sanding, and salting) supplement automated anti-icing when slush or snow accumulates on the bridge deck.

At the end of each winter season the anti-icing system is inspected and reconfigured to spray water instead of potassium acetate. Over the summer, the system is manually activated on a monthly basis to ensure proper operation of the pump and delivery. The system is re-inspected in the fall before being configured for anti-icing during winter operations.

Transportation Outcome: In the first year of operation the automated anti-icing treatment strategy significantly improved roadway safety through a 68-percent decline in winter crashes. Mobility enhancements resulted from reduced traffic congestion associated with such crashes. Installing the bridge anti-icing system also improved productivity by lowering material costs and enhancing winter maintenance operations throughout the district.

Implementation Issues: The Minnesota DOT conducted a feasibility analysis to assess potential benefits and to estimate the costs of deploying an automated anti-icing system on the Interstate 35W bridge. The DOT then contracted with a private vendor to design and install the proprietary hardware and software components, as well as to provide system documentation, training, and support. System installation was completed in December 1999 and calibration and testing was conducted during the 1999/2000 winter season.

Minor hardware and software issues precluded automatic operation until the winter of 2000. Barrier-mounted nozzles were frequently blocked by plowed snow and other nozzles were clogged by sand. Negligible leaking was discovered around some valves. A filter failure in the pump enclosure caused a chemical spill, which reacted with galvanized metals and seeped through the building foundation. The ESS malfunctioned and had to be replaced. Potassium acetate was purchased and delivered in 4,400-gallon quantities necessitating the purchase of an additional chemical storage tank. Software issues included difficulty accessing data and modifying operational parameters. As part of system support, the vendor diagnosed and remedied these problems.

In order to evaluate the anti-icing system, the DOT analyzed weather conditions to identify prior winters that were comparable to the 2000/2001 season. The system evaluation included an analysis of environmental detection capabilities, delivery system pressures, spray characteristics, software alarms, and effects on traffic flow. The evaluation found that the system was activated 501 times, dispensing over 17,000 gallons (64,000 liters) of potassium acetate during winter 2000/2001.

Contact(s):

- Cory Johnson, Minnesota DOT, Office of Metro Maintenance Operations, 651-582-1431, cory.johnson@dot.state.mn.us.

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Keywords: ice, snow, winter storm, pavement condition, pavement temperature, anti-icing/deicing system, freeway management, traveler information, advisory strategy, winter maintenance, treatment strategy, chemicals, bridge, environmental sensor station (ESS), crashes, safety, mobility, productivity

Montana DOT Anti-Icing/Deicing Operations

On December 14, 2000 a winter storm threatened State Route 200 in Montana. The Missoula Maintenance Division of the Montana Department of Transportation (DOT) maintains the Plains section of this route. The Thompson Falls section is maintained by the Kalispell Maintenance Division. Although temperatures were comparable, only eight inches (20 centimeters) of snow fell on the Plains section. In the Thompson Falls area, the storm was more severe with 15 inches (38 centimeters) of snow followed by eight hours of freezing rain. The divisions applied different operational techniques to treat snow and ice.

System Components: Winter maintenance managers in both areas employ mobile treatment strategies in response to winter storm threats. Maintenance vehicles equipped with liquid chemical storage and spray systems are used to treat roads. Liquid magnesium chloride is applied to anti-ice and deice pavement. Abrasives are also spread on roadways to improve traction.

Thompson Falls Section

Plains Section

System Operations: In the Plains section, maintenance vehicles applied 3,000 gallons (11,355 liters) of magnesium chloride during and after the storm, resulting in bare pavement conditions. On the road section in Thompson Falls, 800 gallons (3,028 liters) of chemical were used to pre-wet abrasives before application to compacted snow. Another 750 gallons (2,839 liters) of magnesium chloride were used for anti-icing and deicing in an air quality non-attainment area.

Once the storm passed, numerous complaints were received from drivers due to striking differences in road surface conditions in the area separating the Plains and Thompson Falls road sections. The pavement was bare in Plains section, while the Thompson Falls section was compacted with snow and ice.

Transportation Outcome: To understand what caused the differences, the DOT's Maintenance Review Section interviewed maintenance managers and analyzed material usage and operating costs from 1997 to 2000. Four-year averages are listed in the following table. The treatment strategy utilized in the Plains section costs 37 percent less than the approach used in Thompson Falls, representing increased productivity. A higher roadway level of service was achieved in the Plains section resulting in safety and mobility enhancements. Environmental outcomes were improved by minimizing abrasive usage; which contributes to poor air quality, drainage facility damage, and negative impacts on wildlife habitats.

Montana DOT Winter Maintenance Annual Averages

	Thompson Falls Section	Plains Section	Percent Difference
Sand Quantities	73 cubic yards (56 cubic meters)	43 cubic yards (33 cubic meters)	41%
Sand Costs per lane mile	$724	$407	44%
MgCl Costs per lane mile	$136	$233	N/A
Material Costs per lane mile	$860	$640	26%
Equipment Costs per lane mile	$327	$182	44%
Labor Costs per lane mile	$564	$273	52%
Total Costs per lane mile	**$1,750**	**$1,095**	**37%**

Implementation Issues: Interviews conducted by the DOT's Maintenance Review Section revealed that institutional factors impact winter maintenance operations. The review of operational procedures and roadway impacts revealed that managers had varying interpretations of level of service guidelines and different budgetary concerns. A comparison of treatment strategies demonstrated the benefits of preventive versus reactive treatment strategies. By applying anti-icing chemicals before or at the beginning of a storm event, compacted snow was avoided or easily removed. Reactive treatment required multiple material applications and only temporarily improved traction on snow-covered roads.

Managers in the Plains section typically ordered anti-icing chemicals for an average winter and allowed field supervisors to order additional chemicals as needed. Due to adequate material supplies, anti-icing chemicals were readily dispensed and a relatively high chemical content (i.e., 7.5 percent salt-to-sand) was used in abrasive applications. Kalispell maintenance managers estimated chemical quantities at the beginning of winter and did not purchase additional materials through the season. This more conservative approach was employed to ensure that materials were available throughout the winter. Consequently, the chemical content of abrasives applied in Thompson Falls was only four percent salt-to-sand. Liquid magnesium chloride was used primarily for pre-wetting of abrasives and direct application to pavement was limited to non-attainment areas.

Since the Maintenance Review Section has shown that proactive treatment is cost effective, Kalispell managers have increased the chemical content of salt-to-sand from four to seven percent. Maintenance managers plan to conduct further evaluations of anti-icing strategies and to examine and modify operational guidelines, as appropriate.

Contact(s):
- Dan Williams, Montana DOT Maintenance Review Section, 406-444-7604, dawilliams@state.mt.us.

Reference(s):
- Williams, D. and Linebarger, C., "Winter Maintenance in Thompson Falls," Montana Department of Transportation Maintenance Division, December 2000.

Keywords: snow, ice, winter storm, anti-icing/deicing operations, winter maintenance, freeway management, treatment strategy, institutional issues, maintenance vehicle, chemicals, costs, safety, mobility, productivity

Montana DOT High Wind Warning System

When high winds blow across Interstate 90 in the Bozeman/Livingston area the Montana Department of Transportation warns motorists and manages vehicle access. Severe wind tunnel conditions occur frequently on a 27-mile (43-kilometer) section of the freeway, posing a safety risk to high-profile vehicles.

Wind Warning System Location

System Components: Traffic managers utilize an Environmental Sensor Station (ESS) to monitor wind direction and wind speed. The ESS is part of a statewide Road Weather Information System (RWIS), which collects and transmits environmental data to district offices via a Wide Area Network. Four Dynamic Message Signs (DMS) are installed on the roadway to display messages to eastbound and westbound motorists.

System Operations: Traffic managers employ an advisory strategy to alert motorists of high wind conditions and a control strategy to restrict high-profile vehicle access during severe crosswinds. Traffic and maintenance managers are alerted by the RWIS when wind speeds in the area exceed 20 mph (32 kph). A warning message—"CAUTION: WATCH FOR SEVERE CROSSWINDS"—is displayed on DMS when wind speeds are between 20 and 39 mph. When severe crosswinds (i.e., over 39 mph (63 kph)) are detected, a restriction message is posted on DMS to direct specified vehicles to exit the freeway and take an alternate route through Livingston. A typical restriction message reads "SEVERE CROSSWINDS: HIGH PROFILE UNITS EXIT". DMS may also be used to warn drivers of poor pavement conditions (i.e., snow or ice) during winter months.

Transportation Outcome: Before DMS were installed, maintenance personnel had to erect barricades on the freeway to prevent high-profile vehicles from entering the affected highway section and being blown over or blown off of the road. Advising drivers and restricting access under high wind conditions has improved roadway safety, as well as the productivity and safety of maintenance staff.

Implementation Issues: Two DMS were strategically located on each end of the affected road segment to warn motorists traveling in both directions. The third and fourth DMS were installed in the middle of the 27-mile segment. Wind tunnel conditions are most severe between mileposts 330 and 338. One DMS was placed at milepost 311 for eastbound traffic approaching the area. Two DMS were mounted back-to-back at milepost 330 for both directions. The last DMS was positioned at milepost 338 to inform westbound drivers as they enter the threatened section.

Contact(s):

- Ross Gammon, Bozeman Area Maintenance Chief, 406-586-9562, rgammon@state.mt.us.

Reference(s):

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Keywords: wind, snow, ice, high wind warning system, freeway management, traffic management, traveler information, advisory strategy, motorist warning system, control strategy, access restriction, environmental sensor station (ESS), road weather information system (RWIS), dynamic message signs (DMS), high-profile vehicles, safety, productivity

Nevada DOT High Wind Warning System

The Nevada Department of Transportation (DOT) operates a high wind warning system on a seven-mile (11-kilometer) section of US Route 395. This highway segment, which is located in the Washoe Valley between Carson City and Reno, often experiences very high crosswinds (up to 70 mph or 113 kph) that pose risks to high-profile vehicles. The system provides drivers with advanced warning of high wind conditions and prohibits travel of designated vehicles during severe crosswinds.

System Components: An Environmental Sensor Station (ESS) is installed on the highway to collect and transmit environmental data to a central control computer in the Traffic Operations Center. The ESS measures wind speed and direction, precipitation type and rate, air temperature and humidity, as well as pavement temperature and condition (i.e., wet, snow or ice). During high wind conditions advisory or regulatory messages are displayed on Dynamic Message Signs (DMS) located at each end of the valley. Traffic managers may also broadcast pre-recorded messages via three Highway Advisory Radio transmitters in the area.

High Wind Warning on DMS

System Operations: The central control computer polls the ESS every ten minutes to compare average wind speeds and maximum wind gust speeds to preestablished threshold values. If the average speed exceeds 15 mph (or 24 kph) or the maximum wind gust is over 20 mph (or 32 kph) the computer prompts display of messages as shown in the table below. This is accomplished through an interface with a DMS computer, which runs proprietary software to control the roadside signs. Roadway access to high-profile vehicles is restricted when winds are extreme. Static signs identify critical vehicle profiles and direct specified vehicles to exit the highway and travel on an alternate route when "PROHIBITED" messages are displayed.

Nevada DOT High Wind Warning System Messages

Conditions		Displayed Messages
Average Wind Speeds	**Maximum Wind Gust Speeds**	
15 mph to 30 mph	20 mph to 40 mph	High-profile vehicles "NOT ADVISED"
Greater than 30 mph (48 kph)	Greater than 40 mph (or 64 kph)	High-profile vehicles "PROHIBITED"

Transportation Outcome: Dissemination of traveler information and access restriction have enhanced safety by significantly reducing high-profile vehicle crashes caused by instability in high winds.

Implementation Issues: In the early 1980s the first high wind warning system was constructed on US Route 395. It was comprised of an anemometer (or wind speed sensor), message signs, a relay, and a timer. Because this legacy system needed extensive repairs, it was replaced in the 1990s. A solar-powered ESS was installed in place of the anemometer and relay components, and each message sign was substituted with a DMS.

While developing equipment requirements and operational procedures for the system upgrade, the DOT worked with the University of Nevada to determine warning threshold values. The University analyzed the stability of various vehicle profiles, configurations, and loadings to calculate critical wind speeds (i.e., sufficient speeds to blow vehicles over).

In 1996 the DOT's statewide telephone communication system and Very High Frequency radio network were replaced with a digital, wireless radio communication system. A Wide Area Network (WAN) facilitated the integration of voice, video, and data using open system protocols. The WAN also allowed dissemination of traveler information via the Internet (*www.nvroads.com)* and through telephone systems (*1-877-NVROADS*) with interactive voice response technologies. The computing and communication networks were designed with the flexibility to easily incorporate new technologies or components.

Contact(s):
- Richard Nelson; District Engineer, Nevada DOT District 2, 775-834-8344, rnelson@dot.state.nv.us.
- Denise Inda, Traffic Engineer (ITS), Nevada DOT District 2, 775-834-8320, dinda@dot.state.nv.us.

Reference(s):

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Keywords: wind, high-profile vehicles, high wind warning system, freeway management, traffic management, control strategy, access restriction, advisory strategy, traveler information, internet/website, environmental sensor station (ESS), dynamic message signs (DMS), highway advisory radio (HAR), safety

New Jersey Turnpike Authority Speed Management

The New Jersey Turnpike Authority (NJTA) operates an Advanced Traffic Management System (ATMS) to control 148 miles (237.9 kilometers) of the turnpike, which is one of the nation's most heavily traveled freeways. Various subsystems are employed to monitor road and weather conditions, manage traffic speeds, and notify motorists of hazardous conditions. Speed management and traveler information techniques have improved roadway safety in the presence of fog, snow, and ice.

System Components: ATMS control computers are located at the turnpike Traffic Operations Center in New Brunswick. Data transmission between field components and central control systems is accomplished via a wireless communication system using Cellular Digital Packet Data technology. A vehicle detection subsystem, which is comprised of inductive loop detectors and Remote Processing Units, is utilized to collect speed and volume data and to detect traffic congestion. A Closed Circuit Television subsystem may also be used to visually verify road conditions.

The turnpike's Road Weather Information System includes 30 environmental sensing sites. Three types of environmental sensors are deployed along the turnpike to gather road weather data. Nine Environmental Sensor Stations (ESS) detect wind speed and direction, precipitation type and rate, barometric pressure, air temperature and humidity, as well as visibility distance. Pavement temperature and condition data is collected at 11 sites, while ten others simply monitor visibility distance.

Traveler information is conveyed to motorist through 106 Dynamic Message Signs (DMS), nine Highway Advisory Radio (HAR) transmitters, and a Variable Speed Limit (VSL) subsystem. Over 120 VSL sign assemblies are positioned along the freeway at one-mile (1.6-kilometer) intervals to modify speed limits. Sign assemblies include VSL signs and speed warning signs, which display "REDUCE SPEED AHEAD" messages and reasons for reductions (i.e., "FOG", "SNOW", or "ICE").

System Operations: Traffic and emergency management personnel in the TOC monitor environmental data to determine when speed limits should be lowered. When reductions are warranted, VSL sign assemblies are manually activated to decrease speed limits in five-mph increments from 50, 55, or 65 mph (80.4, 88.4, or 104.5 kph) to 30 mph (48.2 kph) depending on prevailing conditions. System operators may also disseminate regulatory and warning messages via DMS and HAR. State police officers enforce the lower speed limits. When the vehicle detection and RWIS subsystems indicate that traffic and weather conditions have returned to normal, the original speed limits are restored.

Transportation Outcome: The speed control strategy effectively decreases traffic speeds in adverse conditions. Speed management and traveler information dissemination have improved safety by reducing the frequency and severity of weather-related crashes.

Implementation Issues: The turnpike's VSL subsystem is one of the oldest in the country. In the 1950s, before the system was installed, State police officers would patrol the freeway in inclement weather and temporarily nail up plywood signs to reduce speed limits. The VSL system was originally installed in the 1960s and upgraded in the 1980s.

Contact(s):

- Spencer W. Purdum, NJTA Maintenance Department, 732-247-0900, purdum@turnpike.state.nj.us.

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Keywords: fog, visibility, adverse weather, snow, ice, winter storm, speed management, freeway management, emergency management, traffic control, control strategy, motorist warning system, advisory strategy, traveler information, vehicle detection, environmental sensor station (ESS), road weather information system (RWIS), dynamic message sign (DMS), variable speed limit (VSL), highway advisory radio (HAR), crashes, safety

City of New York, New York Anti-Icing/Deicing System

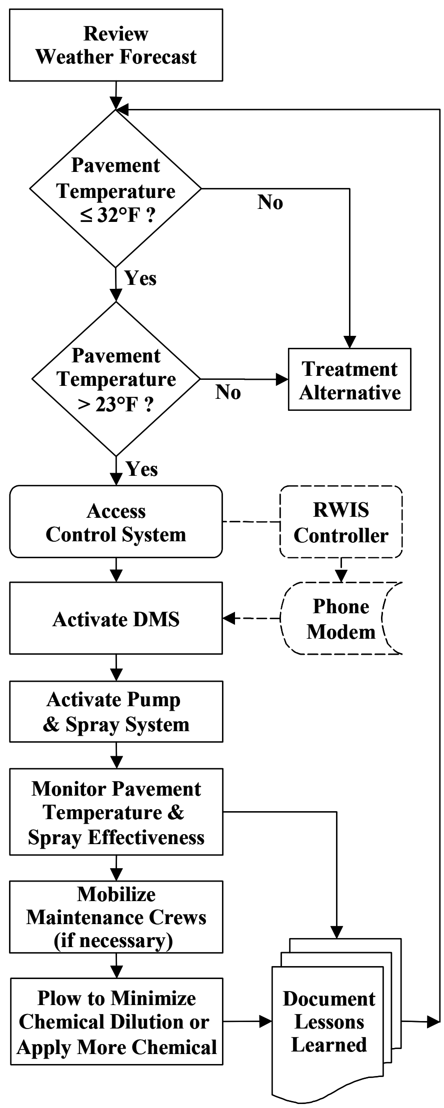
The New York City Department of Transportation (DOT) developed a fixed anti-icing system prototype for a portion of the Brooklyn Bridge. The system sprays an anti-icing chemical on the bridge deck when adverse weather conditions are observed. Anti-icing reduces the need to spread road salt, which has contributed to corrosion of bridge structures.

System Components: The anti-icing system is comprised of a control system, a chemical storage tank containing liquid potassium acetate, a pump, a network of PVC pipes installed in roadside barriers, check valves with an in-line filtration system, 50 barrier-mounted spray nozzles, and a Dynamic Message Sign (DMS). The DMS displays warnings to alert motorists during spray operations. A Closed Circuit Television (CCTV) camera allows operators to visually monitor the anti-icing system.

Each self-cleaning nozzle delivers up to three gallons (11.4 liters) of chemical per minute at a 15-degree spray angle. This angle minimizes misting that could reduce visibility. Two nozzle configurations were implemented to investigate different spray characteristics. On both sides of one bridge section, nozzles were installed 20 feet (6.1 meters) apart for simultaneous spraying. On another section, sequential spray nozzles were mounted on only one side of the bridge.

System Operations: System operators consult television and radio weather forecasts to make road treatment decisions. When anti-icing is deemed necessary, "ANTI-ICING SPRAY IN PROGRESS" is posted on the DMS and the system is manually activated to spray potassium acetate on the pavement for two to three seconds, delivering a half-gallon per 1,000 square feet (1.9 liters per 92.9 square meters).

Operators then review forecasts and view CCTV video images to monitor weather and pavement conditions. If there is a 60 percent or greater chance of precipitation and pavement temperatures are predicted to be lower than the air temperature, maintenance crews are mobilized to supplement anti-icing operations with plowing to remove snow and ice.



Operational Sequence

Transportation Outcome: An analysis of maintenance operations found that bridge sections treated with the anti-icing system had a higher level of service than road segments treated by maintenance vehicles equipped with plows and truck-mounted chemical sprayers. Road segments treated by the anti-icing system have less snow accumulation that bridge sections treated with traditional methods. Pavement conditions during a snow event on January 14, 1999 are depicted below.

Evaluation results indicated that the anti-icing system improves roadway mobility and safety in inclement weather. The system was most effective when chemical applications were initiated at the beginning of weather events. If potassium acetate was sprayed more than an hour before a storm, vehicle tires dispersed the chemical necessitating subsequent applications. The system also improves productivity by extending the life of bridges and minimizing treatment costs associated with mobilizing maintenance crews, preparing equipment, and traveling to treatment sites on congested roads.

Bridge Section Treated with Anti-Icing System

Implementation Issues: Corroded steel grid members were observed in the concrete bridge deck during routine repaving operations in the summer of 1998. The anti-icing system prototype was designed to apply a less corrosive chemical than salt and to minimize the need for road infrastructure repairs. During system design and testing various chemical delivery configurations were examined to determine the appropriate spray pattern, angle, and pressure. Due to concerns about bridge deck integrity, nozzles were barrier-mounted rather than embedded in the road surface.

Bridge Section Treated with Truck-Mounted Sprayer

System performance was evaluated over the 1998/1999, 1999/2000, and 2000/2001 winter seasons. The evaluation included an assessment of the capabilities and reliability of system components, documentation of spray area coverage, a review of road treatment procedures and results, and a cost analysis comparing the anti-icing system to conventional treatment techniques.

The DOT would like to expand the anti-icing system by integrating a Road Weather Information System (RWIS) with the control system, the CCTV camera, and the DMS to improve treatment decision-making. A wireless or fiber optic cable communication network is envisioned for connectivity of these elements. Deployment of the system on the entire Brooklyn Bridge and on other local bridges is also anticipated.

Contact(s):

- Brandon Ward, New York City DOT, Project Manager, 212-788-1720, bward2@dot.nyc.gov.

Reference(s):

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Keywords: snow, ice, winter storm, anti-icing/deicing system, freeway management, winter maintenance, bridge, forecasts, treatment strategy, chemicals, maintenance vehicle, air temperature, pavement temperature, pavement condition, traveler information, advisory strategy, dynamic message sign (DMS), closed circuit television (CCTV), safety, mobility, productivity

City of Charlotte, North Carolina Weather-Related Signal Timing

In North Carolina, the City of Charlotte Department of Transportation (DOT) manages the operation of 615 traffic signals with a computerized control system. In the central business district weather-related signal timing plans are utilized at 149 signals to reduce traffic speeds during severe weather conditions. Weather-related signal timing can also be employed at over 350 intersections controlled by closed-loop signal systems.

System Components: The traffic signal control system is comprised of signal controllers located at City intersections, a Closed Circuit Television (CCTV) surveillance system, twisted pair cable and fiber optic cable communication systems, and a signal system control computer in the Traffic Control Center (TCC). Images from over 25 CCTV cameras on major arterial routes are transmitted to the TCC and displayed on video monitors. Various timing plan patterns, which are stored in the signal computer, can be selected and downloaded to field controllers via the communication systems.

System Operations: System operators assess traffic and weather conditions by viewing CCTV video images and receiving weather forecasts. Forecast data is available through radio and television broadcasts, the National Weather Service (NWS) website, and a private weather service vendor. When heavy rain, snow, or icy conditions are observed operators access the signal computer and manually implement weather-related timing plans. To slow the progression speed of traffic these signal timing plans increase the cycle length—which is typically 90 seconds—while offsets and splits remain the same. During off-peak periods operators may also select peak period timing patterns, which are designed for lower traffic speeds.

System operators monitor roadway operations after weather-related signal timing plans have been executed. If warranted by field conditions, operators can increase cycle lengths to further reduce traffic speeds. When road weather conditions return to normal, operators access the central computer to restore normal time-of-day/day-of-week timing plans.

Transportation Outcome: By selecting signal timing plans based upon prevailing weather conditions traffic managers have improved roadway safety by reducing speeds and minimizing the probability and severity of crashes. Travel speeds decrease by five to ten mph (eight to 16 kph) when weather-related signal timing is utilized.

Implementation Issues: The City's TCC is typically staffed during AM and PM peak periods. However, traffic managers may extend the hours of operation when adverse weather is predicted or observed. System operators may be required to come in early or stay late depending upon the timing and nature of a storm event.

The signal operations staff is very experienced. Most system operators have worked for the City of Charlotte for over ten years. Decisions to execute weather-related signal timing are based upon operator observations, knowledge, and judgment. Road weather conditions are closely monitored to determine the type of storm and its area of influence. Operators modify signal timing only when weather impacts are widespread and affect a significant portion of the City's intersections.

Renovation of the TCC is expected to be complete by the end of 2002. The signal system control computer will be replaced, a new projection screen and new video monitors will be installed, a six-workstation control console will be positioned in the control room, and a fiber optic cable communication link will be established with the North Carolina DOT Traffic Management Center (TMC). This link will facilitate data sharing and allow the City to access video from roughly 30 state-owned CCTV cameras.

Contact(s):

- Art Stegall; City of Charlotte DOT, Signal System Supervisor; 704-336-3914, astegall@ci.charlotte.nc.us.
- Bill Dillard; City of Charlotte DOT, Chief Traffic Engineer; 704-336-3912, wdillard@ci.charlotte.nc.us.

Reference(s):

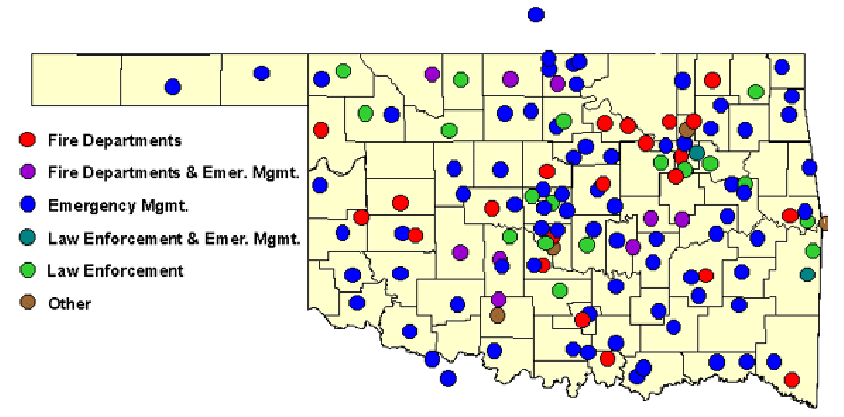
- City of Charlotte DOT Web Site, http://www.ci.charlotte.nc.us/citransportation/cdot.html.

Keywords: rain, snow, ice, weather-related signal timing, arterial management, traffic management, traffic control, control strategy, forecasts, weather information, closed circuit television (CCTV), speed, crashes, safety

Oklahoma Environmental Monitoring System

Public safety officials with various agencies utilize OKlahoma's First-response Information Resource System using Telecommunications (OK-FIRST) to accurately identify weather threats and make effective public safety decisions. OK-FIRST is a decision support system that facilitates data sharing and provides emergency managers with web-based, real-time environmental data.

System Components: Through the information system, emergency managers obtain agency-specific, county-level weather data from the Oklahoma mesoscale environmental monitoring network (i.e., mesonet) and various radar systems. The mesonet includes over 110 Environmental Sensor Stations. The OK-FIRST web site and electronic bulletin board system also foster communication and information sharing among various public safety agencies in different jurisdictions. The Oklahoma Department of Public Safety maintains a leased-line, digital communication network named the Oklahoma Law Enforcement Telecommunications System (OLETS). Over 200 participants access OK-FIRST through OLETS including law enforcement, emergency management, and fire service agencies.



OK-FIRST Participants

System Operations: Mesonet data is packaged into five-minute observations and transmitted via OLETS and a radio communication system to the University of Oklahoma for quality assurance, integration with National Weather Service data, and dissemination via the web. Emergency managers access OK-FIRST to identify and respond to severe storms, tornadoes, flooding, and wild fires.

Transportation Outcome: On May 3, 1999 over 50 tornadoes impacted northern and central Oklahoma damaging nearly 10,000 buildings, and causing 44 fatalities and over 700 injuries. In Seminole County emergency response vehicles were traveling to the Oklahoma City area on Interstate 40. With information from OK-FIRST the county's emergency manager identified a developing tornado that would cross the freeway in front of the emergency vehicle convoy. When responders were notified they stopped near Shawnee, Oklahoma and closed the interstate to prevent response and passenger vehicles from driving into the tornado's path.

Emergency managers in Logan County spotted a tornado in the path of an ambulance transporting a critically injured victim from Crescent to a hospital in Guthrie, Oklahoma. Ambulance personnel were instructed to halt the vehicle until the tornado had passed. These decisions ensured the safety of both response personnel and the traveling public.

Emergency managers have also used OK-FIRST to respond to flood events. In one county, emergency managers monitored rainfall amounts during a storm, and closed a susceptible bridge before it was washed away. In another county, emergency managers observed water levels within six inches (15.2 centimeters) of flood stage, but decided to do nothing. Information from OK-FIRST indicated that the threat had passed as waters were receding. In addition to enhancing safety OK-FIRST results in productivity improvements by decreasing the number of storm spotters and by minimizing overtime for winter road maintenance personnel.

Implementation Issues: In 1996 OK-FIRST was funded by a grant from the Technology Opportunities Program (formerly the Telecommunications Information and Infrastructure Assistance Program), sponsored by the US Department of Commerce. The DPS has provided support funding since that time. After system components were installed, integrated, and tested all participating agencies were offered training on the Oklahoma Mesonet to learn how access to environmental information could enhance their operations. An independent evaluation found that the knowledge and skills of OK-FIRST users were significantly enhanced.

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Keywords: adverse weather, tornado, flooding, environmental monitoring system, emergency management, law enforcement, decision support, advisory strategy, institutional issues, weather information, environmental sensor station (ESS), internet/website, safety

South Carolina Hurricane Evacuation Operations

In September 1999 roughly three million people were evacuated from coastal areas in Florida, Georgia, North Carolina, and South Carolina prior to landfall of Hurricane Floyd. Over 500,000 South Carolinians evacuated from six coastal counties. Because managers with the South Carolina Department of Transportation (DOT) and the South Carolina Department of Public Safety had not agreed on a lane reversal plan prior to Hurricane Floyd, contraflow (i.e., lane reversal) was not employed during the evacuation. Consequently, there was severe congestion on Interstate 26 between Charleston and Columbia. Traffic and emergency managers quickly developed a contraflow plan for reentry operations after the hurricane.

System Components: Managers utilized storm track, wind speed, and precipitation forecast data in combination with population density and topographic information to identify areas threatened by storm surge and inland flooding. Emergency managers consulted various information sources including the National Weather Service, the National Hurricane Center, the Federal Emergency Management Agency, as well as decision support applications such as HURREVAC (*www.hurrevac.com*) and HurrTrak (*www.weathergraphics.com/ht/*). Traffic managers monitored traffic flow with two permanent vehicle detection sites along the highway and portable detection equipment on other road facilities. During reentry operations, portable Dynamic Message Signs (DMS) and Highway Advisory Radio (HAR) transmitters were positioned along the interstate to alert drivers of contraflow operations.

System Operations: DOT managers worked closely with Highway Patrol personnel during evacuation and reentry operations. Traffic and emergency managers also coordinated with other local, state, and federal agencies. Before traffic flow on westbound lanes could be reversed for reentry (i.e., contraflowed from Columbia to Charleston), DOT and DPS personnel were mobilized and equipment was prepositioned. Lanes to be reversed were cleared of all traffic, and traffic control devices and barricades were erected. Access ramps to westbound lanes and some minor interchanges were closed. Highway Patrol personnel staffed all closed ramps and patrol vehicles were stationed along the 95-mile (152.7-kilometer) contraflow route to manage incidents. Traffic managers continuously polled vehicle detectors to monitor traffic operations.

Contraflow Operations

Transportation Outcome: On Tuesday, September 14th the Governor issued a voluntary evacuation order at 7:00 AM followed by a mandatory evacuation order at noon. In response, over 350,000 people evacuated on Tuesday and roughly 160,000 departed on Wednesday. The timing of evacuation orders, the public's response to the orders, the lack of lane reversal operations, and unmanned traffic signals in small towns contributed to severe congestion on Interstate 26 between Charleston and Columbia. Travel time, which is normally 2½ hours, ranged from 14 to 18 hours during the evacuation. The maximum per lane volume on the interstate was 1,445 vehicles per hour.

The Governor ordered contraflow operations to minimize travel times during reentry. Traffic and emergency managers quickly developed a contraflow plan to accommodate reentry traffic in reversed westbound lanes. DMS and HAR were deployed to notify travelers of closures and alternate routes. As a result of contraflow, the maximum volume during reentry was 2,082 vehicles per hour per lane—a 44 percent increase over evacuation volumes. Contraflow operations and dissemination of traveler information significantly improved mobility by increasing roadway capacity and traffic volumes.

Implementation Issues: When planning contraflow operations managers must designate routes, determine initiation and termination points, select a contraflow strategy, establish criteria for implementation, arrange enforcement and incident management, promote institutional coordination, as well as communicate with political officials and the public. Geometric modifications to the roadway or special traffic control patterns may be required at contraflow initiation and termination points. After Hurricane Floyd, the South Carolina DOT constructed and X-shaped median crossover with a 45-mph (72-kph) design speed. During normal traffic operations, a water-filled barrier prevents vehicles from crossing into the wrong lanes. The barrier can be drained and removed by two people when lanes are reversed. Short connecting roads may have to be constructed between ramps and freeway lanes to facilitate access in the opposite direction. In Charleston, the DOT constructed a short road segment between a ramp from Interstate 526 to Interstate 26 in order to provide outbound traffic access to inbound lanes.

Other geometric and operational considerations include the condition and width of shoulder lanes, bridge widths, guardrail treatments, and separating traffic flows at termination points to prevent congestion caused by merging normal and reversed lanes. Where contraflow terminates in Columbia, traffic in normal lanes will be detoured onto Interstate 77. After the Interstate 26/Interstate 77 interchange, traffic in reversed lanes will cross the median to access the normal westbound lanes of Interstate 26.

After initiation and termination points are designed, one of four contraflow strategies must be selected. The first strategy reverses all coast-bound lanes. The second contraflow strategy reverses all but one coast-bound lane for use by emergency and patrol vehicles involved in incident management. In addition to emergency and patrol vehicles, the third contraflow strategy allows passenger vehicles to use the single coast-bound lane. The fourth strategy utilizes an inbound shoulder lane for evacuating traffic and reverses all but one coast-bound lane.

Traffic control devices and law enforcement officers should be positioned at initiation points, termination points, and closed facilities to ensure roadway safety. The National Guard may be activated to assist with these duties. Construction work zones should also be removed and shoulders should be cleared of debris before contraflow operations begin.

Traffic volumes and speeds should be monitored throughout contraflow operations. This information may be useful in determining when lane reversal should be terminated or when alternate routes should be considered. Vehicle detection devices on reversed lanes and processing software must to be capable of counting vehicles and calculating speeds in the opposite direction.

Criteria and procedures for implementing and terminating contraflow must be established prior to hurricane season. Implementation criteria may include mobilization time, minimum traffic volumes, and daylight hours. Contraflow must be terminated in time to clear the route of all traffic prior to landfall, secure or remove susceptible equipment, and ensure the safety of personnel in the field. Lane reversal operations typically end two hours before hurricane landfall is expected.

Dissemination of pre-trip and en-route traveler information, as well as institutional coordination are other considerations. Emergency and traffic managers at county and state levels must communicate effectively. Multi-state coordination is also critical. During the Hurricane Floyd evacuation managers in South Carolina worked with managers in Georgia to facilitate smooth traffic flow across the state boundary.

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Keywords: hurricane, wind, precipitation, flooding, hurricane evacuation operations, freeway management, emergency management, law enforcement, traffic management, institutional issues, control strategy, traffic control, access restriction, advisory strategy, traveler information, forecasts, weather information, decision support, vehicle detection, dynamic message sign (DMS), highway advisory radio (HAR), volume, mobility

South Carolina DOT Low Visibility Warning System

As a result of a federal court decision the South Carolina Department of Transportation (DOT) was required to incorporate fog mitigation technologies during construction of the Interstate 526 Cooper River Bridge. The DOT deployed a low visibility warning system on seven miles (11.3 kilometers) of the freeway to inform drivers of dense fog conditions, reduce traffic speeds, and guide vehicles safely through the fog-prone area.

System Components: Warning system components include an Environmental Sensor Station (ESS), five forward-scatter visibility sensors spaced at 500-foot (152.4-meter) intervals, pavement lights installed at 110-foot spacing (33.5-meter), adjustable street light controls, eight Closed Circuit Television (CCTV) cameras, eight Dynamic Message Signs (DMS), a Remote Processing Unit (RPU), a central control computer, and a fiber optic cable communication system. The ESS measures wind speed and direction, air temperature, and humidity. The on-site RPU transmits field sensor data to the control computer, which is located in a DOT district office.

System Operations: The central computer's decision support software predicts or detects foggy conditions, correlates environmental data with predetermined response strategies, and alerts traffic managers in the district office. When alerted by the computer, system operators view images from the CCTV cameras to verify reduced visibility conditions. Operators may accept or decline response strategies recommended by the computer system. Potential advisory and control strategies include displaying pre-programmed messages on DMS, illuminating pavement lights to guide vehicles through the fog, extinguishing overhead street lights to minimize glare, and closing the freeway and detouring traffic to Interstate 26 and US Highway 17. When warranted, Highway Patrol officers erect barricades to close the freeway. Response strategies for various visibility ranges are shown in the following table.

South Carolina DOT Low Visibility Warning System Response Strategies

Visibility Conditions	Advisory Strategies	Control Strategies
700 to 900 feet (213.4 to 274.3 meters)	"POTENTIAL FOR FOG" and "LIGHT FOG CAUTION" on DMS	"LIGHT FOG TRUCKS 45 MPH" and "TRUCKS KEEP RIGHT" on DMS
450 to 700 feet (137.2 to 213.4 meters)	"FOG CAUTION" and "FOG REDUCE SPEED" on DMS	Pavement lights illuminated
		"FOG REDUCE SPEED 45 MPH" and "TRUCKS KEEP RIGHT" on DMS
300 to 450 feet (91.4 to 137.2 meters)	"FOG CAUTION" on DMS	Pavement lights illuminated and overhead street lighting extinguished
		"FOG REDUCE SPEED 35 MPH" and "TRUCKS KEEP RIGHT" on DMS
Less than 300 feet	N/A	Pavement lights illuminated and overhead street lighting extinguished
		"DENSE FOG REDUCE SPEED 25 MPH" and "TRUCKS KEEP RIGHT" on DMS
		If warranted, "PREPARE TO STOP", "I-526 BRIDGE CLOSED AHEAD USE I-26/US 17", and "ALL TRAFFIC MUST EXIT" on DMS

Transportation Outcome: The low visibility warning system enhances mobility by providing traveler information and clearly delineating travel lanes with pavement lights. Regarding safety, no fog-related crashes have occurred since the system was deployed.

Implementation Issues: The owner of a paper mill near the Cooper River Bridge site filed a lawsuit against the South Carolina DOT as they planned construction of the bridge in the mid-1980s. The bridge was to be built at the same height as the paper mill's smoke stacks. After reviewing various fog mitigation techniques recommended by a consulting firm, a federal judge required that a low visibility warning system be included in the bridge construction project.

The warning system began operating in 1992. Initially, there were several system reliability problems related to the harsh, outdoor environment. In order to prevent unnecessary activations system software was calibrated to average visibility distance observations and disregard low readings caused by smoke plumes from the paper mill. Components of the microwave communication system, which was originally deployed, were struck by lightning and ultimately replaced by the fiber optic cable communication system. The DOT permitted the installation of privately owned communication cables in the state's right-of-way in exchange for dedicated fibers from the project site to the district office.

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Keywords: fog, visibility, low visibility warning system, freeway management, traffic management, advisory strategy, motorist warning system, traveler information, control strategy, speed management, access restriction, decision support, environmental sensor station (ESS), closed circuit television (CCTV), dynamic message sign (DMS), vehicle guidance, lighting, high-profile vehicles, safety, mobility

Tennessee Low Visibility Warning System

On December 11, 1990 the visibility distance on a segment of Interstate 75 in southeastern Tennessee was less than 10 feet (3.1 meters). Extremely low visibility contributed to chain-reaction collisions in northbound and southbound lanes involving 99 vehicles, 42 injuries, and 12 fatalities. This crash prompted the design and implementation of a low visibility warning system on the interstate freeway. The system covers 19 miles (30.6 kilometers) including a three-mile (five-kilometer), fog-prone section above the Hiwassee River and eight-mile (13-kilometer) road sections on each side of the river.

System Components: Managers with the Tennessee Department of Transportation (DOT) and the Tennessee Department of Safety access a central computer system that collects data from two Environmental Sensor Stations, eight forward-scatter visibility sensors, and 44 vehicle detectors. Underground fiber optic cables transmit sensor data from the roadway to an on-site computer for processing. Data from the on-site computer is relayed via a microwave communication system to the central computer in the Highway Patrol office in Tiftonia. Traffic and emergency managers employ both advisory and control strategies. Motorists are notified of prevailing conditions via flashing beacons atop six static signs, two Highway Advisory Radio (HAR) transmitters, and ten Dynamic Message Signs (DMS). Roadside delineator posts with highly reflective stripping are spaced roughly 80 feet (24.4 meters) apart throughout the project area for visual observation of visibility conditions. Speed management is accomplished by controlling ten Variable Speed Limit (VSL) signs. When necessary, access to the affected highway section is restricted with eight gates located on interchange ramps.

VSL Sign

System Operations: By continually monitoring sensor data, the on-site computer predicts and detects conditions conducive to fog formation and detects significant reductions in traffic speed. The central computer sounds an audible alarm in the Highway Patrol office when established threshold criteria are met. When alerted dispatchers post a reduced speed message on DMS and notify Highway Patrol troopers. Troopers are stationed in the project area from 5 AM to 10 AM when most fog events occur. Within five minutes of an alarm troopers verify conditions by counting the number of visible delineator posts.

Control software provides decision support by correlating field sensor data with pre-determined response scenarios. When troopers confirm low visibility conditions, managers select pre-programmed DMS messages (see table below), pre-recorded HAR messages, and appropriate speed limits based upon scenarios proposed by the central computer. The system also allows the display or broadcasting of customized messages. The speed limit is reduced from 65 to 50 mph (105.4 to 80.4 kph) when visibility is between 480 and 1,320 feet (146.3 and 402.3 meters). The limit is lowered to 35 mph (56.3 kph) for visibility distances between 240 and 480 feet.

Ramp Gate

Under the worst-case scenario—visibility less than 240 feet or 73.2 meters—Highway Patrol troopers activate automatic ramp gates to close the interstate and detour traffic to US Highway 11. Low visibility has caused freeway closures twice since the warning system was deployed; once due to fog and once due to smoke from a nearby fire.

Tennessee Low Visibility Warning System Messages

Conditions	Displayed Messages
Reduced Speed Detected	"CAUTION" alternating with "SLOW TRAFFIC AHEAD"
Fog Detected *	"CAUTION" alternating with "FOG AHEAD TURN ON LOW BEAMS"
Speed Limit Reduced **	"FOG AHEAD" alternating with "ADVISORY RADIO TUNE TO XXXX AM"
	"FOG AHEAD" alternating with "REDUCE SPEED TURN ON LOW BEAMS"
	"FOG" alternating with "SPEED LIMIT XX MPH"
Roadway Closed ***	"DETOUR AHEAD" alternating with "REDUCE SPEED MERGE RIGHT"
	"I-75 CLOSED" alternating with "DETOUR →"
	"FOG AHEAD" alternating with "ADVISORY RADIO TUNE TO XXXX AM"

* "FOG" is displayed on VSL signs. ** "FOG" and reduced speed limits are displayed on VSL signs, and HAR messages are broadcast. *** "FOG" is displayed on VSL signs, HAR messages are broadcast, and ramp gates are closed.

Transportation Outcome: The low visibility warning system is activated about once a week, primarily from October to March. Ninety-five percent of system activations result in a speed limit reduction to 50 mph. There have been over 200 crashes, 130 injuries and 18 fatalities on this highway section since the interstate opened in 1973. Safety has significantly improved after deployment of the warning system in 1994, as only one fog-related accident has occurred.

Implementation Issues: When planning the Interstate 75 system, traffic managers assessed another low visibility warning system in Charleston, South Carolina. Device technologies, system components, and operational procedures were evaluated to assist Tennessee managers with system design. After developing requirements for equipment, communications, and power supply DOT managers determined system scope (i.e., coverage of the most fog-prone area), field equipment locations, and warning messages. To ensure system reliability, backup radio and telephone communication systems, as well as an emergency power system were installed.

Some system integration problems were experienced during implementation. There were minor complications associated with hardware failures due to the harsh outdoor environment. Traffic managers have been unable to observe system status or receive alerts due to trouble with data transmission from the project site to the regional DOT office.

System designers addressed system maintenance and expandability. Both routine and emergency maintenance are performed regularly on system components. The system was planned to accommodate future integration of new technologies or components, including a digital Closed Circuit Television surveillance system.

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Keywords: fog, visibility, low visibility warning system, freeway management, traffic management, emergency management, law enforcement, advisory strategy, motorist warning system, traveler information, control strategy, speed management, access restriction, decision support, vehicle detection, environmental sensor station (ESS), variable speed limit (VSL), dynamic message signs (DMS), highway advisory radio (HAR), gates, crashes, safety

City of Dallas, Texas Flood Warning System

In May 1995 a rain event caused widespread flooding in the City of Dallas, Texas resulting in seven roadway fatalities. The City deployed an automated system to monitor water levels at over 40 stream locations near roads and warn motorists of high water until maintenance personnel can barricade dangerous roads.

System Components: The flood warning system consists of stilling wells, Remote Processing Units (RPUs), Dynamic Message Signs (DMS), a radio communication system, and a central computer system. A stilling well is comprised of a 3-foot (0.9-meter) long pipe, a pressure transducer, and a float switch to measure stream levels. When high water is detected, RPUs activate sign assemblies and report stream levels to the central computer. Each RPU—which is housed in a pole-mounted enclosure—includes radio communication devices, solar or electrical power systems, and controls to reset sign assemblies. At each monitoring site, one to four sign assemblies are installed near the road to alert motorists. Sign assemblies include electromechanical DMS, two flashing beacons, radio communication devices, and power systems.

Flood Warning System Sign Assembly

System Operations: When water reaches the roadway edge RPUs automatically activate flashing red beacons and change sign messages from "HIGH WATER WHEN FLASHING" to "DO NOT ENTER HIGH WATER". Sign assemblies send a message back to the RPU to verify proper operation. Remote processing units transmit water level and sign status to the central computer every hour via the radio communication system. When high water is detected by field components, the central computer is immediately alerted and sends alphanumeric pages to maintenance staff who then erect barricades on threatened roads. The central computer also posts road closures on the City's "Flooded Roadway Warning System" web site (*www.ci.dallas.tx.us/sts/html/frws.html*). When the water recedes, maintenance staff are paged again to notify them that barricades can be removed and signs assemblies can be reset.

Transportation Outcome: The flood warning system improves roadway safety, as most motorists heed sign warnings and avoid hazardous conditions. Further, since the system was installed in April 2000 no claims related to flooded roads have been filed against the City.

Implementation Issues: During system design the City identified sites warranting motorist notification. Locations with a history of flooding or where drowning deaths had occurred were selected. After field equipment locations were selected, system requirements were established. The City desired a cost effective warning system that could be integrated with existing hydrologic monitoring systems, including the Automated Local Evaluation in Real-Time (ALERT) system and the Supervisory Control and Data Acquisition (SCADA) system.

System designers considered using gate arms to restrict roadway access. Gate configurations were eliminated due to their high costs and history of damage by vehicles attempting to circumvent them. To reduce deployment costs, solar power supply systems were designed for most monitoring sites. Electric power service was arranged for a few sites in shaded areas. Incorporating RPUs that technicians were familiar with further minimized deployment costs associated with training.

Because the City could be held liable if warning signs do not activate during flooding, all field equipment is serviced and tested frequently. All field components are inspected, cleaned, and calibrated every six months. Once a month, maintenance personnel travel to each monitoring site and manually activate sign assemblies to ensure proper operation.

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Keywords: rain, flooding, flood warning system, arterial management, traffic management, advisory strategy, motorist warning system, dynamic message signs (DMS), control strategy, access restriction, safety

Utah DOT Fog Dispersal Operations

In northern Utah widespread, super-cooled fog (i.e., less than 32 degrees F) can persist in mountain valleys for weeks. Utah Department of Transportation (DOT) maintenance personnel use liquid carbon dioxide to disperse fog and improve visibility along segments of Interstates 15, 70, 80, and 84; US Highways 40, 89, and 91; as well as secondary roads in Cache Valley and Bear Lake Valley. This treatment strategy includes the application of anti-icing chemicals as fog is dispersed to prevent moisture from freezing on the pavement.

System Components: Fog dispersal equipment, comprised of commercially available products, is installed on roughly 70 maintenance vehicles or 15 percent of the fleet. Each truck is equipped with a compressed gas cylinder, a manual valve assembly, mounting brackets, copper pipe, and a dispensing nozzle. Each cylinder holds liquid carbon dioxide at a pressure of 2,000 pounds per square inch (psi).

System Operations: Before vehicles leave the maintenance yard for normal patrol duties, the cylinder and valve assembly are attached. Dispensers are turned on when maintenance vehicles leave the yard and turned off when they return. As the vehicles travel through super-cooled fog, very small amounts of liquid carbon dioxide are sprayed into the slipstream of the truck. The carbon dioxide quickly evaporates removing heat from water droplets in the fog. The droplets form ice crystals and precipitate as fine snow or ice.

To prevent the precipitate from freezing on the road surface, anti-icing chemicals are simultaneously applied. If the air temperature is below 20 degrees F (-6.7 degrees C), common road salt is prewetted with liquid magnesium chloride and applied to pavements. Road salt or sodium chloride brine is spread when the air temperature is above 20 degrees F.

Maintenance Vehicle equipped with Fog Dispersal Equipment

Transportation Outcome: The fog dispersal treatment strategy improves roadway mobility and safety. This strategy can increase visibility distance behind the maintenance vehicle from 33 feet (10 meters) to 1,640 feet (500 meters) in less than 30 minutes. The treatment remains effective for 30 minutes to 4 hours, depending upon air temperature and wind speed. Improved visibility has significantly reduced rear-end crashes into maintenance vehicles, enhancing the safety of DOT personnel and the public.

Implementation Issues: In 1990 the DOT's Research Division sponsored a University of Utah research grant to investigate fog control at a bridge location. During the study university researchers noticed that a tunnel of clear visibility formed in the fog as carbon dioxide was dispensed. In 1992 DOT and university researchers developed a prototype with customized hardware components and began the field testing of mobile fog dispersal techniques. The Research Division published field trial results in 1993.

Based upon recommendations in the field trial report and lessons learned from anti-icing operations near Salt Lake International Airport, maintenance personnel configured a truck with fog dispersal equipment composed of commercial-off-the-shelf products. This configuration was more cost effective than the customized configuration developed by the University, which was prohibitively expensive.

Before fog dispersal equipment was deployed in 2000, the DOT developed a two-hour training course to ensure employee safety when working with compressed liquid carbon dioxide. Training course topics included oxygen-displacement properties of the chemical, chemical handling techniques, and operation of the high-pressure dispenser.

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Keywords: fog, visibility, air temperature, wind, fog dispersal operations, freeway management, winter maintenance, treatment strategy, maintenance vehicle, chemicals, anti-icing/deicing, crashes, safety, mobility

Utah DOT Low Visibility Warning System

Due to high traffic volumes and local conditions conducive to dense fog formation, the Utah Department of Transportation (DOT) deployed a low visibility warning system on Interstate 215 to notify motorists of safe travel speeds and to promote more uniform traffic flow. The warning system was installed on a low-lying, two-mile (three-kilometer) highway segment above the Jordan River in Salt Lake City where multi-vehicle, fog-related crashes have occurred.

System Components: Four forward-scatter visibility sensors and six vehicle detection sites are installed on the freeway to collect data on prevailing conditions. Visibility distance is measured in real-time and inductive loop detectors record the speed, length, and lane of each vehicle. Through Ultra-High Frequency radio modems these data are transmitted to a central computer system that records field data in a database, processes field data, and posts advisories on two roadside Dynamic Message Signs (DMS).

System Operations: The central computer identifies threats by using visibility distance, vehicle speed, and vehicle classification data in a weighted average algorithm to determine when conditions warrant motorist warnings. When visibility distance falls below 820 feet (250 meters), the computer automatically displays a warning on DMS. Based on stopping sight distances, safe travel speeds are posted on DMS when visibility is less than 656 feet (200 meters). Messages displayed for various visibility ranges are shown in the table below.

Utah DOT Low Visibility Warning System Messages

Visibility Conditions	Displayed Messages
656 to 820 feet (200 to 250 meters)	"FOG AHEAD"
492 to 656 feet (150 to 200 meters)	"DENSE FOG" alternating with "ADVISE 50 MPH"
328 to 492 feet (100 to 150 meters)	"DENSE FOG" alternating with "ADVISE 40 MPH"
197 to 328 feet (60 to 1000 meters)	"DENSE FOG" alternating with "ADVISE 30 MPH"
Less than 197 feet (60 meters)	"DENSE FOG" alternating with "ADVISE 25 MPH"

Transportation Outcome: An evaluation of the warning system indicated that overly cautious drivers sped up when advisory information was displayed, resulting in a 15 percent increase in average speed from 54 to 62 mph (86.8 to 99.7 kph). This increase caused a 22 percent decrease in speed variance from 9.5 to 7.4 mph (15.3 to 11.9 kph). Reducing speed variance enhanced mobility and safety by promoting more uniform traffic flow and minimizing the risk of initial, secondary, and multi-vehicle crashes.

Implementation Issues: In 1993 DOT researchers responded to a federal solicitation to prototype a low visibility warning system. The DOT contracted with a consultant in 1994 to design and install the system on Interstate 215 due to recurring fog. During winter 1995/1996 the DOT collected visibility distance and traffic data before DMS were deployed to assess driver behavior in fog without advisories. By the end of 1997 field, central, and communication equipment was installed, calibrated, and integrated. DMS calibration and verification was carried out with the assistance of the Utah Highway Patrol.

The system was operational by winter 1999/2000 and traffic managers began collecting traffic speed data, vehicle classification data, visibility data, as well as a log of displayed messages. The DOT partnered with the University of Utah to conduct an evaluation of system effectiveness. The University analyzed traffic speeds by time-of-day, lane and direction, vehicle classification, and visibility distance with data collected over four winter seasons. Based on positive results, it was recommended that that speed and pavement condition data be incorporated into control logic, that the warning system be integrated with the DOT's Advanced Traffic Management System, and that further evaluation be conducted. Future studies will include analysis of crash rates in low visibility conditions before and after warning system deployment.

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Reference(s):

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- Perrin, et al., "Testing the Adverse Visibility Information System Evaluation (ADVISE) – Safer Driving in Fog," presented at the Transportation Research Board (TRB) Annual Meeting, January 2002.

Keywords: fog, low visibility warning system, freeway management, traffic management, control strategy, speed management, advisory strategy, motorist warning system, traveler information, vehicle detection, dynamic message sign (DMS), driver behavior, safety, mobility

Virginia DOT Weather-Related Incident Detection

The Virginia Department of Transportation (DOT) operates an Advanced Traffic Management System (ATMS) to control the highway network in Northern Virginia. The ATMS includes an Incident Detection subsystem and a Closed Circuit Television (CCTV) subsystem, which are used for traffic and road condition surveillance on 27 miles (43.4 kilometers) of Interstate 66 and nearly 29 miles (46.6 kilometers) of Interstate 395. Traffic managers are able to modify incident detection parameters based upon observed weather conditions.

System Components: The Incident Detection subsystem is comprised of inductive loop detectors, Type 170 controllers housed in roadside cabinets, and a central incident detection computer. Traffic flow data is collected at over 120 vehicle detection sites installed every half mile (0.8 kilometers) along the freeways. The CCTV subsystem includes over 50 cameras, video transmission devices, and three monitor walls for display of video images. Fiber optic cable and coaxial cable communication systems transmit data and video from the field to control computers in the Smart Traffic Center (STC) located in Arlington.

System Operations: Incident detection computer software contains statistical algorithms that continuously analyze field data to identify traffic flow disruptions caused by incidents. Traffic managers may select databases containing detection algorithms for “clear”, “rainy” or “snowy” conditions. When rain or snow events are observed on the monitor walls traffic managers access the incident detection computer and select the detection database most appropriate for prevailing conditions. The CCTV subsystem is also used to visually verify detected incidents and support incident management activities.

Transportation Outcome: Use of algorithms tailored to specific weather events improves roadway mobility and safety by facilitating incident detection under non-ideal conditions. Weather-related incident detection enhances mobility by minimizing response time and traffic delays associated with temporary capacity reductions. Safety is improved through expedited incident response and clearance, which reduce the risk of secondary crashes.

Implementation Issues: The Virginia DOT contracted with a consulting firm to design, install, and integrate ATMS components and subsystems. In 1985 system integration and testing efforts were completed and the STC began operating. The ATMS was expanded in 1999 through the deployment of additional monitoring, control, and communication devices along Interstates 66 and 95.

Hardware and software components in the STC were upgraded in 2000. The original mainframe computer was replaced with redundant servers. New operator workstations and video walls were also installed. In the future, the DOT plans to expand weather-related incident detection capabilities to Interstate 495 (i.e., the Capital Beltway) and plans to integrate the ATMS with research facilities at the University of Virginia.

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Keywords: rain, snow, pavement condition, weather-related incident detection, freeway management, control strategy, incidents, vehicle detection, closed circuit television (CCTV), safety, mobility

Washington State DOT Speed Management

Interstate 90 is the primary east-west route across Washington State. This freeway crosses the Cascade Mountains through Snoqualmie Pass, which is a popular tourist destination. Roadway geometry, the volume of truck traffic (i.e., 22 percent), and recreational travelers unfamiliar with local conditions contribute to a high winter crash rate. The Washington State Department of Transportation (DOT) employs a speed management technique on a 40-mile (64-kilometer) segment of the freeway to improve roadway safety in the presence of fog, snow, and ice.

System Components: The speed management system is comprised of Environmental Sensor Stations (ESS), radar vehicle detectors, Remote Processing Units (RPUs) housed in roadside cabinets, Dynamic Message Signs (DMS), Variable Speed Limit (VSL) signs, a central control system, as well as digital radio and microwave communication systems. Six ESS are installed along the interstate to detect air temperature and humidity, precipitation, wind speed, pavement temperature and condition (e.g., dry, wet, icy), and pavement chemical concentration. ESS data and vehicle speed data are collected by RPUs and transmitted to a control computer in the maintenance office located in Hyak. Advisory messages and reduced speed limits are posted on the DMS and VSL signs.

Reduced Speed Limit on DMS

System Operations: The central control computer provides decision support by utilizing software algorithms to process field data, calculate safe speeds, and suggest speed limit reductions during adverse conditions. If system operators agree with the recommendations DMS and VSL signs are activated to display road weather advisories, reduced speed limits, and the reasons for lower speeds. The control computer allows system operators to modify speed limits by direction and by road section. DMS may also be used to alert drivers of roadway closures necessitated by winter maintenance and avalanche control activities.

When warranted, the speed limit is reduced in 10-mph (16-kph) increments from 65 mph to 35 mph (56.3 kph) based upon prevailing road, weather, and traffic conditions. Vehicle equipment (e.g., tire chains) may be regulated to improve vehicle traction. Control strategies for various road weather conditions are shown in the following table.

Washington State DOT Speed Management Control Strategies

Weather Conditions	Pavement Conditions	Control Strategies
• Light to moderate rain • Visibility distance greater than 0.5 miles (0.80 kilometers)	• Dry or wet	• Speed limit at 65 mph (104.5 kph) • No tire regulations
• Heavy rain • Fog • Visibility distance less than 0.2 miles (0.32 kilometers)	• Slushy or Icy	• Speed limit reduced to 55 mph (88.4 kph) • Traction tires advised
• Heavy rain or snow • Blowing snow • Visibility distance less than 0.1 miles (0.16 kilometers)	• Shallow standing water • Compacted snow or ice • Deep slush	• Speed limit reduced to 45 mph (72.4 kph) • Traction tires required
• Freezing rain • Heavy rain or snow • Blowing snow • Visibility distance less than 0.1 miles (0.16 kilometers)	• Deep standing water • Deep snow or slush	• Speed limit reduced to 35 mph (56.3 kph) • Tire chains required

Transportation Outcome: Speed management has improved roadway safety by prompting drivers to decrease speed in inclement conditions. This control strategy also impacts roadway mobility by minimizing speed variance, which results in more uniform traffic flow.

Implementation Issues: An examination of historical crash statistics determined that the winter crash rate was significantly higher than the annual average. Crash frequency in the presence of snow was five times the rate under clear conditions. The crash rate in January was 12 times higher that the July crash rate. High travel speeds and speed variance were found to contribute to winter crashes, which were primarily rear-end, sideswipe, and run-off-the-road type. Based upon these findings, the Washington State DOT decided to employ speed management to enhance roadway safety under low visibility or slippery pavement conditions.

The DOT hired a consultant to provide design, integration, and support services for system components. The DOT selected field equipment locations, designed sign support structures, assessed communication system options, and purchased DMS hardware. The DOT's Radio Operations department considered the licensing, installation, and maintenance issues associated with telephone, radio, microwave, and satellite communications technologies. The cost of installing 40 miles (64 kilometers) of telephone cable through the mountainous terrain of the Snoqualmie Pass was prohibitive. High costs and topography also precluded utilization of satellite communications. Thus, multiple microwave and radio communication links were designed to transmit data from the roadway to the mountaintop and from the mountaintop to the Hyak maintenance office. The DOT chose a DMS technology with high visibility in adverse weather conditions and procured the signs under a separate contract to ensure that performance criteria were met.

After system components were deployed in winter 1997, the Washington State DOT established policies and procedures to guide system operation. Traffic managers, system operators, maintenance personnel, state police, and others involved with the system were consulted during development of these policies. Policies and procedures covered staffing and training requirements, the reporting structure, message sets, and various response scenarios.

Contact(s):

- Larry Senn, Washington State DOT, Olympia Traffic Operations Office, 206-543-6741, larsenn@u.washington.edu.

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Keywords: fog, visibility, snow, ice, winter storm, speed management, freeway management, traffic management, traffic control, law enforcement, access restriction, control strategy, motorist warning system, traveler information, advisory strategy, decision support, high-profile vehicles, vehicle detection, environmental sensor station (ESS), pavement condition, dynamic message sign (DMS), variable speed limit (VSL), driver behavior, speed, crashes, safety

Wyoming DOT Avalanche Warning System

US Highway 189 near Jackson, Wyoming is a steep, mountain road that winds through Hoback Canyon. Along the highway, there is an avalanche path with a 35-degree slope that poses a threat to the traveling public and to Wyoming Department of Transportation (DOT) personnel engaged in snow and ice control activities. In the past, maintenance personnel have been caught in avalanches while clearing snow and debris from a prior slide. The DOT has deployed a warning system on the highway to detect avalanches, warn approaching motorists, and alert maintenance personnel working in the area.

System Components: The avalanche warning system is comprised of a sensor assembly, a radio communication system, a controller, two static warning signs equipped with flashing beacons, and audible alarms in maintenance vehicles. The sensor assembly includes tilt switch sensors enclosed in galvanized steel pipes. The pipes are hung on weighted wire ropes attached to a ¾-inch (19-mm) diameter cable, which is strung across the slide path. The cable is suspended roughly 8 feet (2.5 meters) above the ground and anchored to steel posts embedded in concrete. The sensor assembly is installed 980 feet (298.7 meters) above the roadway.


Avalanche Path on US Highway 189

The controller monitors sensor status, records sensor data, and activates warning systems via radio when the onset of an avalanche is detected. The roadside warning signs are located 1,300 feet (396.2 meters) in advance of the affected highway segment. Batteries with solar panel chargers supply power to all field sensors, control devices, and communications hardware. Portable alarm devices are placed in maintenance vehicles—primarily rotary snowplows and front-end loaders—operating in the area.

System Operations: Controller software is programmed to continuously monitor the sensor assembly and detect switch closure based upon established threshold values. When an avalanche is detected, warning devices are instantly activated. Tilt switches within the steel pipes pivot from vertical to horizontal positions when impacted by a slide causing a circuit to close. The controller automatically prompts a radio to transmit a modulated tone to activate beacons atop motorists warning signs and to sound 97-decibel sirens in maintenance vehicles. The audible alert gives maintenance personnel about ten seconds to move out of the slide path.

Transportation Outcome: The avalanche warning system improves roadway safety by minimizing risks to drivers and to maintenance personnel. The system also facilitates timely inspection of the roadway after an avalanche, snow and debris removal activities, and road closure or rescue operations.

Implementation Issues: The warning system project was initiated as a multi-state, pooled fund study involving Colorado, Idaho, Utah, Washington State, and Wyoming. After developing equipment requirements, designers of the Wyoming system decided where the sensor assembly should be installed based upon starting zones and slide speeds of prior avalanches. If sensors were located too far above the highway, the system could initiate warnings for avalanches that did not reach the road. If placed too close to the road, there would not be sufficient time for the system to warn those in danger.

Designers considered system expandability through the integration of new components. A preliminary test of non-invasive avalanche sensors is underway. Two geophones, which measure ground motion, were installed adjacent to the slide path roughly 98 and 197 feet (30 and 60 meters) below the tilt switch sensor assembly. When the tilt switch sensors are activated, the controller simultaneously samples the geophones. By detecting the time lag in the arrival of an avalanche waveform, the controller can distinguish avalanches from other events and determine slide velocity. Further experimentation is necessary to establish criteria for warning system activation.

In a coordinated effort, local winter maintenance managers and emergency managers plan to examine hardware and communication interface reliability, document system operation, and assess roadway impacts. Evaluation results will be used to optimize the system and supplement training.

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- Rand Decker, University of Utah, 801-581-3403, rdecker@civil.utah.edu.

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Keywords: snow, avalanche warning system, freeway management, winter maintenance, advisory strategy, traveler information, motorist warning, maintenance vehicle, safety

Acronym List

AFWS	Automated Flood Warning System
AASHTO	American Association of State Highway and Transportation Officials
ATIS	Advanced Traveler Information System
ATMS	Advanced Traffic Management System
AVCS	Advanced Vehicle Control System
B/C	Benefit/Cost
BMP	Best Management Practice
CCTV	Closed Circuit Television
CDPD	Cellular Digital Packet Data
CMAQ	Congestion Mitigation and Air Quality
DMS	Dynamic Message Sign
DOT	Department of Transportation
DPS	Department of Public Safety
DSL	Digital Subscriber Line
DSS	Decision Support System
EOC	Emergency Operations Center
ESS	Environmental Sensor Station
FHWA	Federal Highway Administration
GPS	Global Positioning System
HAR	Highway Advisory Radio
HAZMAT	Hazardous Material
ISP	Information Service Provider
ITS	Intelligent Transportation System
MMDI	Metropolitan Model Deployment Initiative
NCHRP	National Cooperative Highway Research Program
NWS	National Weather Service
OFCM	Office of the Federal Coordinator for Meteorology
OK-FIRST	Oklahoma's First-response Information Resource System using Telecommunications
OLETS	Oklahoma Law Enforcement Telecommunications System
PC	Personal Computer
PVC	Polyvinyl Chloride
RPU	Remote Processing Unit
RWIS	Road Weather Information System

SCADA	Supervisory Control And Data Acquisition
SHEP	State Highway Emergency Patrol
STC	Smart Traffic Center
TCC	Traffic Control Center
TOC	Traffic Operations Center
TMC	Traffic Management Center
TRIS	Transportation Research Information Services
UHF	Ultra-High Frequency
US	United States
USDOT	United States Department of Transportation
UTCS	Uniform Traffic Control System
VHF	Very High Frequency
VSL	Variable Speed Limit
WAN	Wide Area Network

Online Resources

WEB SITE	INTERNET ADDRESS (URL)
FHWA Road Weather Management Program	http://www.ops.fhwa.dot.gov/weather/index.htm
Maintenance Decision Support System (MDSS)	http://www.rap.ucar.edu/projects/rdwx_mdss/demo/index.html
ITS Resource Guide	http://www.its.dot.gov/itsweb/guide.html
ITS America	http://www.itsa.org
Aurora Program	http://www.aurora-program.org/
Enterprise Program	http://www.enterprise.prog.org/
Evacuation Traffic Information System (ETIS)	http://www.fhwaetis.com/etis/
Snow and Ice Cooperative Program (SICOP)	http://www.sicop.net/
Cooperative Program for Operational Meteorology, Education and Training (COMET)	http://www.comet.ucar.edu/cometprogram.htm
The Office of the Federal Coordinator for Meteorology (OFCM)	http://www.ofcm.gov/
American Meteorological Society (AMS)	http://www.ametsoc.org/AMS/
National Weather Service (NWS)	http://www.nws.noaa.gov/
NWS Tropical Prediction Center, National Hurricane Center	http://www.nhc.noaa.gov/
World Road Association (PIARC)	http://www.aipcr.lcpc.fr/index-e.htm
Standing International Road Weather Commission (SIRWEC)	http://www.sirwec.org

Publication Listing

TITLE	ABSTRACT	SOURCE
A BENEFIT/COST ANALYSIS OF INTELLIGENT TRANSPORTATION SYSTEM APPLICATIONS FOR WINTER MAINTENANCE	Washington State DOT assessed the benefits and costs of deploying an automated anti-icing system on a high-accident corridor.	Transportation Research Board 80th Annual Meeting, Search TRIS http://199.79.179.82/sundev/search.cfm
A DECISION SUPPORT SYSTEM FOR SNOW EMERGENCY VEHICLE ROUTING: ALGORITHMS AND APPLICATION	Summarizes results of research to develop a decision support system to assist the Maryland State Highway Administration Office of Maintenance staff design snow emergency routes for Calvert County, MD and achieve improvements in service and savings in operational costs.	Transportation Research Board 80th Annual Meeting, Search TRIS http://199.79.179.82/sundev/search.cfm
A GUIDE FOR SELECTING ANTI-ICING CHEMICALS, V1.0	The purpose of the guide is to specify the key performance measures that are required from an anti-icing chemical, and suggest ways of grading chemicals according to those performance measures. It also provides a method whereby an agency can weight these measures according to the specific needs of that agency.	www.anti-ice-guide.com
A LIFE CYCLE COST-BENEFIT MODEL FOR ROAD WEATHER INFORMATION SYSTEMS	Describes a decision tool supporting implementation of RWIS and quantification of costs and benefits.	Transportation Research Board 77th Annual Meeting, Search TRIS http://199.79.179.82/sundev/search.cfm
A PORTABLE METHOD TO DETERMINE CHLORIDE CONCENTRATION ON ROADWAY PAVEMENTS	Studies have shown that the ability to measure the salt concentration on roadway surface would bring dramatic advances in the effective use of deicers. Concentration measurement devices currently in use are only for point measurement and are dangerous for field personnel because they require manual on-site measurement. A new portable concentration system developed in this project is mounted on a truck and enables safer and continuous measurement of salt concentration.	Transportation Research Board 81st Annual Meeting, Search TRIS http://199.79.179.82/sundev/search.cfm
ADVANCED COLLISION WARNING SYSTEM FOR THE ROADVIEW SNOWPLOW DRIVER ASSISTANCE SYSTEM	Research program conducted in California and Arizona on Advanced Snowplow with a multi-lane, radar-based Advanced Collision Warning system and a magnetic Lateral Sensing System for use in low visibility conditions. A visual display provides two-dimensional driver assistance information.	7th World Congress on ITS, University of California - Davis.

TITLE	ABSTRACT	SOURCE
ADVANCED TRAVELER INFORMATION SERVICE (ATIS): WHAT DO ATIS CUSTOMERS WANT?	This is the second of two white papers written for the “ATIS Data Gap” workshop with the objective of providing insights from MMDI Customer Satisfaction ATIS evaluations and other USDOT-sponsored ATIS research. The paper synthesizes findings from research and evaluations dating back to 1996, including several field operational tests.	www.itsdocs.fhwa.dot.gov/\JPODOCS\REPTS_TE/9H801!.PDF
ADVANCED VEHICLE CONTROL SYSTEMS (AVCS) FOR MAINTENANCE VEHICLE APPLICATIONS	Highway maintenance operations most suitable for the application of AVCS are snow removal and work zone following by a shadow vehicle. This study explores opportunities for AVCS-based snow removal and work zone following vehicles. A description of these operations, and their suitability for the application of AVCS is presented. Previous and on-going work related to vehicle automation for these operations is introduced, along with recommendations for the future, based on an assessment of technical feasibility of AVCS and the attitudes of the highway and airport maintenance communities towards this technology.	http://ahs.volpe.dot.gov/avcsdoc/p1report.pdf
ADVERSE WEATHER TRAFFIC SIGNAL TIMING	Study conducted for Minnesota DOT to determine the impact of bad weather on a coordinated signal system (three-mile section of Trunk Highway 36 with five signals) and to determine if it would be beneficial to develop timing plans to accommodate adverse weather conditions.	www.trafficware.com/documents/1999/00005.pdf
AN ASSESSMENT OF SELECT METROPOLITAN WASHINGTON PUBLIC SAFETY AND TRANSPORTATION AGENCIES USER NEEDS	Study of integrated information projects within the transportation community nationwide.	www.capwinproject.com/extras/reports/user_needs_assessment.pdf
AN INDEPENDENT EVALUATION OF THE OK-FIRST DECISION-SUPPORT SYSTEM	The Oklahoma Climatological Survey (OCS) implemented a DSS known as OKlahoma's First-response Information Resource System using Telecommunications to provide public safety officials with customized, county-level environmental information within minutes of observation.	http://okfirst.ocs.ou.edu/press/preprints/2envapps/1_11.pdf

TITLE	ABSTRACT	SOURCE
AN INVESTIGATION OF INCIDENT FREQUENCY, DURATION AND LANES BLOCKAGE FOR DETERMINING TRAFFIC DELAY	Traffic delay caused by incidents is closely related to three variables: incident frequency, incident duration, and the number of lanes blocked by an incident. Relatively, incident duration has been more extensively studied than incident frequency and the number of blocked lanes. In this study, we provided an investigation of the influencing factors for all of these three variables based on an incident data set that was collected in New York City. The information about the incidents derived from the identification can be used by incident management agencies in New York City for strategic policy decision making and daily incident management and traffic operations. Rain is the only factor that significantly influenced incident frequency.	Transportation Research Board 81st Annual Meeting, Search TRIS http://199.79.179.82/sundev/search.cfm
ANALYZING THE EFFECTS OF WEB-BASED TRAFFIC INFORMATION AND WEATHER EVENTS IN THE SEATTLE PUGET SOUND REGION: DRAFT REPORT	Analysis of web-based ATIS usage logs against observed weather conditions, and generation of a new profile of ATIS market penetration. Simulation results were analyzed and compared to results from Mitretek's earlier MMDI study. Analysis showed that non-uniform ATIS utilization rate related to severe weather has a small positive impact on road system efficiency.	Mitretek Systems, ITS Division
ANOTHER STEP TOWARD A NATIONALLY INTEGRATED TRAVELER INFORMATION SYSTEM	Overview of traveler information including definition, explanation of growth, USDOT role and vision, and next steps.	www.itsdocs.fhwa.dot.gov/jpodocs/periodic/8ph01!.htm
ANTI ICING SUCCESS FUELS EXPANSION OF THE PROGRAM IN IDAHO	Idaho Transportation Department anti-icing success story on section of US Highway 12.	www.sicop.net/US-12%20Anti%20Icing%20Success.pdf
APPLICATION OF ADVANCED ITS INTERFACING THAT IMPROVES MAINTENANCE OPERATIONAL EFFECTIVENESS AND WINTER SAFETY IN RURAL AREAS	In 1995, the state DOT's of Iowa, Michigan, and Minnesota formed a consortium to define and develop the next-generation highway maintenance vehicle that would utilize the latest maintenance operational technologies and interface with Intelligent Transportation Systems. This advanced technology highway maintenance vehicle functions as both an operational truck and a mobile data-gathering platform. Sensors mounted on the vehicle record air and roadway surface temperature, roadway surface condition, and roadway surface friction characteristics.	http://www.ctre.iastate.edu/pubs/midcon/front.pdf

TITLE	ABSTRACT	SOURCE
APPLICATION OF JETTING TECHNOLOGY TO PAVEMENT DEICING	Over 20 years ago, the Connecticut DOT investigated the use of pressurized salt brine jets to enhance the deicing performance. Despite promising results from several field trails, technical difficulties led to abandonment of this technology in the early 80's. Recent advances in high pressure jetting technology suggest that the use of high pressure jets in conjunction with improved chemical agents for pavement deicing may now be practical. In this study, the application of modern high pressure jetting technology as a means of pavement deicing is explored. The proposed system removes ice and snow through the combined action of mechanical jetting forces and controlled use of deicing chemicals.	Transportation Research Board 81st Annual Meeting, Search TRIS http://199.79.179.82/sundev/search.cfm
APPLICATION OF ROAD WEATHER INFORMATION SYSTEMS IN THE WESTERN UNITED STATES	MesoWest software links weather observations from roughly 350 stations in the NWS surface aviation network and 2,100 additional stations, including RWIS stations. MesoWest collects and processes data from over 40 organizations. MesoWest data is available in Montana, Nevada, Utah and Wyoming through cooperative agreements between local NWS offices and state DOT agencies.	www.met.utah.edu/jhorel/html/mesonet/rwis.pdf
APPLICATION OF THE ADVANCED TRAVELER INFORMATION SYSTEMS (ATIS) MESSAGE STANDARD	Mitretek demonstrated an information system that provides route-specific travel forecasts that contain weather, traffic, and road closure information using eXtensible Markup Language (XML). The demonstration used XML data sets from a DOT's web site containing manual weather observations and RWIS data, as well as data from a web-based Pavement Condition Reporting System (PCRS).	8th World Congress on ITS, Mitretek Systems ITS Division
APPLICATIONS OF INTELLIGENT TRANSPORTATION SYSTEMS FOR WINTER MAINTENANCE	This paper describes potential applications of ITS for winter maintenance and provides examples of case studies. Moreover, the paper identifies and discusses the institutional, technical and operational barriers to the implementation of advanced technologies for ice and snow removal.	Transportation Research Board 80th Annual Meeting, Search TRIS http://199.79.179.82/sundev/search.cfm
ARE SIMPLISTIC WEATHER-RELATED MOTORIST WARNING SYSTEMS "ALL WET"?	On a two-lane exit ramp in Ft. Lauderdale, Florida; an automated motorist warning system (including a wet pavement sensor and vehicle detector) that activates flashing beacons atop static speed limit signs. Speed reductions and reduced crash frequency resulted.	7th World Congress on ITS, University of South Florida.
AVALANCHE HAZARD REDUCTION FOR TRANSPORTATION CORRIDORS USING REAL-TIME DETECTION AND ALARMS	Presents configurations of systems that detect and provide warning to motorists and highway maintainers of the onset of avalanching onto the roadway. Warnings include on-site traffic control signing and in-vehicle audio alarms for winter maintenance vehicles.	www.sicop.net/annals-paper%20total.pdf

TITLE	ABSTRACT	SOURCE
BENEFIT/COST STUDY OF RWIS AND ANTI-ICING TECHNOLOGIES	Report describes anti-icing and RWIS research and implementation efforts, and summarizes anti-icing technologies. Benefits and costs as reported in the literature and supplemented with interviews of highway professionals.	www.sicop.net/NCHRP20-7(117).pdf
BEST PRACTICES FOR ROAD WEATHER MANAGEMENT	Weather threatens surface transportation nationwide and impacts roadway mobility, safety, and productivity. There is a perception that traffic managers can do little about weather. However, three types of mitigation measures—control, treatment, and advisory strategies—may be employed in response to environmental threats and impacts. Best management practices include road weather and traffic surveillance to assess threats to transportation system performance, arterial and freeway management to regulate roadway capacity, as well as dissemination of advisory information to influence traveler decisions and driver behavior. These management practices are employed in response to various weather threats including low visibility, high winds, snow, rain, ice, flooding, tornadoes, hurricanes, and avalanches.	Mitretek Systems ITS Division
BEST PRACTICES OF OUTSOURCING WINTER MAINTENANCE SERVICES	Contract language and provisions being used by various owner-agencies in the public sector. Best practices include clear contractual language placing responsibility on private sector to develop, train and equip personnel; confine language to measurable outcome-based performance measures; connect producer-contractor to user-customer; producers proactively responding to RWIS-based predictions and encouraged to utilized anti-icing; seek the sharing of knowledge; and maximize opportunities for the private sector to be responsive, efficient and effective. Appendix D contains sample contract provisions.	www.vmsom.com/images/pdf/Best%20Practices%20Outsourcing%20Winter%20Maintenance%20Services.pdf
CLOSING THE DATA GAP: GUIDELINES FOR QUALITY ADVANCED TRAVELER INFORMATION SYSTEM (ATIS) DATA	ITS America's ATIS Committee developed guidelines to assist public agencies and private firms in generating and using data to support the expansion of ATIS products and services. The focus of these guidelines is limited to real-time or dynamic traffic-related information necessary to offer traveler information services envisioned in the near-term.	www.itsdocs.fhwa.dot.gov//jpodocs/rept_mis/13580.html
CURRENT PRACTICES IN TRANSPORTATION MANAGEMENT DURING INCLEMENT WEATHER	Best practices include road weather and traffic surveillance to assess threats to transportation system performance, arterial and freeway management to regulate roadway capacity, as well as dissemination of advisory information to influence traveler decisions and driver behavior. These management practices are employed in response to various weather threats including low visibility, high winds, precipitation, hurricanes, flooding, and avalanches. Weather-related transportation management practices (1) improve mobility by increasing roadway capacity and promoting uniform traffic flow, (2) increase public safety by minimizing crash risk and exposure to hazards, as well as (3) enhance the safety and productivity of road maintenance personnel.	Institute of Transportation Engineers 2002 Annual Meeting, Mitretek Systems ITS Division

TITLE	ABSTRACT	SOURCE
DECISION SUPPORT SYSTEM FOR WINTER MAINTENANCE: FEASIBILITY DEMONSTRATION	This project reports on existing work in developing decision support tools to select chemical applications appropriate to winter weather conditions, to describe in detail those which are at or near an operational state, and to assess the feasibility of implementation as part of a RWIS. A literature review identified four DSS: an expert system development project by the Swedish National Road Administration (SNRA), a table-based menu for anti-icing developed by FHWA, a computerized adaptation of the FHWA menu, and an expert system development by Swedish Road and Transport Research Institute.	www.aurora-program.org/pdf/decision1and2.pdf
DEVELOPING THE FRAMEWORK OF A DYNAMIC TRAFFIC MANAGEMENT MODEL FOR HURRICANE EVACUATION: SUMMARY REPORT	Paper describes the development of a dynamic hurricane evacuation modeling framework, which can be used for planning and operational purposes. See also TRAFFIC MODELING FRAMEWORK FOR HURRICANE EVACUATION.	Transportation Research Board 79th Annual Meeting, Search TRIS http://199.79.179.82/sundev/search.cfm
DEVELOPMENT OF ROAD SURFACE CONDITION SENSOR USING OPTICAL TEMPERATURE SENSOR AND WEATHER SENSOR	System is comprised of optical fiber embedded in the road and a temperature distribution measurement apparatus to measure longitudinal temperature distribution, ESS, and a judgment apparatus that classifies road conditions into five categories based on the various measurement data.	8th World Congress on ITS, Ministry of Land Infrastructure and Transport, Japan
DEVELOPMENT OF ROAD TEMPERATURE SENSING SYSTEM USING OPTICAL FIBER	Road surface temperature distribution sensing using optical fiber sensor embedded in roadway and ESS data. Tests on two kilometer section of National Route No. 18 in Nagano Prefecture, Japan.	7th World Congress on ITS, Ministry of Construction, Japan
DOCUMENTATION AND ASSESSMENT OF MN/DOT GATE OPERATIONS	Study conducted from March to August 1999 to assess new operational procedure prohibiting access to Interstates during unsafe driving conditions using mainline and ramp gates. Benefits and costs data.	www.dot.state.mn.us/guidestar/pdf/gatereport.pdf
DYNAMIC MESSAGING	The Enterprise program is multi-state pooled-fund study group with a focus on providing effective solutions for rural transportation applications. Enterprise, in cooperation with the Arizonia DOT, is researching solutions for problems motorists face in limited visibility situations. Identifies components of low-visibility warning systems and the techniques deployed by various states that best address improving safety by detecting low visibility events and disseminating advanced information to motorists as well further evaluating low-visibility detection technologies during these conditions.	http://enterprise.prog.org/

TITLE	ABSTRACT	SOURCE
ECONOMIC EVALUATION OF ADVANCED WINTER HIGHWAY MAINTENANCE STRATEGIES	Estimated potential savings in labor and equipment costs of using pavement temperature data to customize material type and application rates.	http://www.ctre.iastate.edu/pubs/midcon/front.pdf
EFFECT OF ENVIRONMENTAL FACTORS ON FREE-FLOW SPEED	Use of Idaho Storm Warning System project data to determine the effects of various weather factors on free-flow speed during 1997/1998 and 1998/1999 winter.	http://www.nas.edu/trb/publications/ec018/10_25.pdf
EFFECTS OF VARIABLE SPEED LIMIT SIGNS ON DRIVER BEHAVIOR DURING INCLEMENT WEATHER	On a two-mile test roadway in Salt Lake Valley, Utah; speed limits are varied based on visibility and traffic conditions using a weighted average algorithm and display via DMS. Reduction in speed deviation, reduction in crash frequency, and increase in overall mean speed resulted.	Institute of Transportaion Engineers 2000 Annual Meeting, University of Utah
EFFECTS OF VARIOUS DEICING CHEMICALS ON PAVEMENT CONCRETE DETERIORATION	Study investigating the effects of different deicers on concrete deterioration. Deicers produce characteristic effects on concrete samples by physically and chemically altering the aggregate, the aggregate-past interface, and the cement paste.	http://www.ctre.iastate.edu/pubs/midcon/front.pdf
EFFICACY AND ECONOMIC EFFICIENCY FOR THAWING AGENTS SPRAY SYSTEMS - FINAL REPORT	With a length of 6 km, the thawing agents spray system used on the A45 (Sauerland line) is the longest installed in Germany. After the installation of this system, the number of crashs on the equipped road section and due to winter road conditions was reduced by more than 50%.	http://www.ops.fhwa.dot.gov/weather/Publications/GermanAnti-icingReport.pdf
ENHANCEMENTS TO THE VIRTUAL WEATHER STATION METHODOLOGY	Representative climatic conditions at any location can be estimated using data from nearby weather stations. The reasonableness of such estimates depends on the quality of weather data as well as method used in developing such estimates. This study investigates the possibility of improving the accuracy of climatic estimates. Four different methods of estimating the climatic parameters were studied and it was found that simple average of climatic parameters from nearby weather stations provides the most reasonable estimate. It was found that the elevation difference between the desired location and nearby weather stations significantly affects estimate bias. A relationship was developed to remove the bias due to elevation difference.	Transportation Research Board 81st Annual Meeting, Search TRIS http://199.79.179.82/sundev/search.cfm
EVALUATION OF A FIXED ANTI-ICING SPRAY TECHNOLOGY (FAST) SYSTEM	This paper desribes the development of Fixed Anit-Icing Spray Techonology (FAST) systems to apply less corrosive liquid chemical freezing-point depressants on portions of the Brooklyn Bridge. During the first phase of the project, several operational parameters were investigated, including spray pattern, spray angle and spray pressure. Phase II of this project describes the proposed extension of the FAST system and integtation of a RWIS.	Transportation Research Board 81st Annual Meeting, Search TRIS http://199.79.179.82/sundev/search.cfm

TITLE	ABSTRACT	SOURCE
EVALUATION OF CALTRANS DISTRICT 10 AUTOMATED WARNING SYSTEM: YEAR TWO PROGRESS REPORT	The Caltrans Automated Warning System (CAWS) entered service in November 1996. The system includes 36 speed monitoring sites, 9 weather stations, 9 DMS and TMC computer systems. Researchers at the University of California carried out the independent evaluation. The report bibliography includes summaries of all highway fog warning systems for which published information was available.	http://www.path.berkeley.edu/PATH/Publications/PDF/PRR/99/PRR-99-28.pdf
EVALUATION OF MOTORISTS WARNING SYSTEMS FOR FOG-RELATED INCIDENTS IN THE TAMPA BAY AREA	Investigation to determine extent of fog patterns and fog-related incidents in the Tampa Bay area, and suitable countermeasures to detect and warn motorists of fog conditions. Fog warning systems in Alabama, Arkansas, Georgia, New Mexico, Tennessee, Idaho, New Jersey, South Carolina, Louisiana, Oregon, Utah and California are discussed. Types of fog, conditions conducive to formation, and visibility detection technologies are also covered.	www.cutr.eng.usf.edu/research/fog.pdf
EVALUATION OF THE FORETELL CONSORTIUM OPERATIONAL TEST: WEATHER INFORMATION FOR SURFACE TRANSPORTATION	Defines strategy for conducing an independent evaluation of the FORETELL project, a regional road and weather forecasting/dissemination system in Iowa, Wisconsin, and Missouri.	http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/7tr01!.pdf
EVALUATION OF THE OPERATION AND DEMONSTRATION TEST OF SHORT-RANGE WEATHER FORECASTING DECISION SUPPORT WITHIN AN ADVANCED RURAL TRAVELER INFORMATION SYSTEM	The Advanced Rural Traveler Information System (ARTIS) aims to provide en-route, operational decision support information including real-time and forecast weather conditions in rural areas. A three-year operational test was designed to measure user acceptance, use of the system for decision making, and use of weather-related data for maintenance operations.	www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/@9301!.pdf
EVALUATION OF THE SEATTLE SMART TREK MODEL DEPLOYMENT INITIATIVE	Evaluation focused on institutional benefits, ATIS customer satisfaction, and ITS integration modeling. The impact of weather events was evident in the December 1998 web site usage levels.	Science Applications International Corporation (SAIC)
EVALUATION REPORT FOR THE EVACUATION TRAVEL DEMAND FORECASTING MODEL: DRAFT	The TDFM is a web-based software tool designed to predict congestion levels on major evacuation routes and predict state-to-state traffic volumes to aid in effective hurricane evacuation planning. Evaluation of the model was based on performance during a tabletop exercise.	Science Applications International Corporation (SAIC)

TITLE	ABSTRACT	SOURCE
EXTRACTION OF THE SLIPPERINESS COMPONENT FROM WEATHER AND TRAFFIC DATA FOR WINTER MAINTENANCE OPERATIONS	While traffic and weather information systems provide the current status of air and road surface temperatures, what many drivers really want to know is not the temperature but the degree of slipperiness. Although the friction coefficient is the best index for snow and ice maintenance operations, it is not so easy to manipulate. Some weather condition data are closely correlated with this friction coefficient. In this study, the substitutability of weather and traffic data is examined quantitatively through analysis of field data observed at an intersection.	Transportation Research Board 81st Annual Meeting, Search TRIS http://199.79.179.82/sundev/search.cfm
FLOOD WARNINGS ON-LINE	In Queensland, Australia; remote sensors are used to monitor creek and river water levels to warn motorists. The Queensland Department of Main Roads and the Royal Automobile Club of Queensland (RACQ) provide road condition information via web page (www.racq.com.au/journey) and toll-free telephone system with interactive voice response (IVR) technology.	ITS International, March/April Issue
FRICTION AS A TOOL FOR WINTER MAINTENANCE	Considers how friction measuring devices might be used operationally. They will likely be used as a measure of quality, as a source of traveler information, and as a means of controlling chemical application.	http://www.ctre.iastate.edu/pubs/crossroads/86friction.pdf
GETTING CLEAR ON FOG-RELATED CRASHES IN TAMPA BAY	Paper discusses a four-step process employed to evaluate advanced fog-detection technologies and suggest possible strategies to address fog-related incidents in the Tampa Bay Area. See also EVALUATION OF MOTORISTS WARNING SYSTEMS FOR FOG-RELATED INCIDENTS IN THE TAMPA BAY AREA.	www.path.berkeley.edu/~leap/itsdecision_resources/articles/S_ite_0200_fog_warning.pdf
HAPPY MOTORING ON SAFER INTERSTATE HIGHWAY: HIGH-TECH FOG WARNING SYSTEM DEVELOPED AT GEORGIA TECH WILL ISSUE ADVISORIES TO MOTORISTS	An automated fog and smoke warning system will be deployed on 14 miles of Interstate 75 near Adel, Georgia. The system includes 19 fog sensors, ESS, speed detectors and CCTV. System software at GDOT's Atlanta TMC analyzes field data and decides which messages to display on four DMS and when to illuminate streetlights. A three-year evaluation is being planned.	http://gtresearchnews.gatech.edu/reshor/rh-ss01/fog.html
HIGHWAY DEICING: COMPARING SALT AND CALCIUM MAGNESIUM ACETATE (SPECIAL REPORT 235)	Deicing chemicals are important tools for highway snow and ice control. The National Research Council conducted a study to examine the full economic costs of using salt and CMA for highway deicing. The report defines the true cost of salt; estimates of monetary costs involved in mitigating environmental damage from road salt; summaries of the field performance, infrastructure and environmental impacts, production technologies and costs of CMA.	http://gulliver.trb.org/publications/sr/sr235.html

TITLE	ABSTRACT	SOURCE
I-35W & MISSISSIPPI RIVER BRIDGE ANTI-ICING PROJECT: OPERATIONAL EVALUATION REPORT	A bridge that spans the Mississippi River on US Interstate 35W in Minneapolis, Minnesota has been fitted with a computerized system that sprays potassium acetate, an anti-icing chemical, on the bridge deck when data from environmental sensors indicate that hazardous winter driving conditions are imminent.	http://www.dot.state.mn.us/metro/maintenance/Anti-icing%20evaluation.pdf
IDAHO STORM WARNING SYSTEM OPERATIONAL TEST	Two phased test conducted on I-84 in southeastern Idaho between 1998 and 1993 to (1) determine accuracy of visibility sensors and (2) whether DMS reduce vehicle speed during low visibility conditions.	http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/@cc01!.pdf
IDENTIFICATION AND DOCUMENTATION OF WEATHER AND ROAD CONDITION DISSEMINATION DEVICES AND DATA FORMATS	This project identifies means for improving consistency and usability of road and weather information presentation through indentification of current and planned road and weather information dissemination systems and synthesis of various means for presenting information to end users.	www.aurora-program.org/pdf/standardinforpt.pdf
IDENTIFICATION OF TRIGGER WIND VELOCITIES TO CAUSE VEHICLE INSTABILITY	Study to determine the critical wind velocity and angle that would overturn different vehicles. A variety of road surface conditions, vehicle types and profiles, vehicle speeds, and vehicle loads are considered to identify the most critical condition.	Nevada DOT District II
IMPROVING PUBLIC RESPONSE TO HURRICANE FLOODING	Operational procedures include forecasts of the storm-total area average rainfall and its location in south Florida by the Miami Weather Forecast Office (WFO). If guidance from the Southeast River Forecast Center (RFC) indicates potential for flooding, a flood watch is issued. If flooding is imminent a flood warning is issued.	American Meteorological Society Symposium on Precipitation Extremes Proceedings
INFORMATION ON THE PLANNING, CONSTRUCTION AND OPERATION OF CHEMICAL THAWING AGENT SPRAYING INSTALLATIONS	Chemical thawing agent spraying systems are fixed equipment of the winter service. Road surface and weather condition detectors detect the ice formation of a road and trigger a thawing agent spraying system into operation. A spraying system allows the timely prevention of icing on hazardous places and assists a conventional (usually mechanical) winter service, by preventing the packing down of the snow layer.	http://www.ops.fhwa.dot.gov/weather/Publications/GermanAnti-icingGuidance.pdf
INTERNET TECHNOLOGY-BASED ROAD INFORMATION SYSTEMS	A method of using eXtensible Markup Language (XML) technology, Road Web Markup Language (RWML) in the road information field is proposed.	http://152.99.129.29/cdrom/3013.pdf

TITLE	ABSTRACT	SOURCE
IOWA DOT WEATHER INFORMATION SYSTEM TO SUPPORT WINTER MAINTENANCE OPERATIONS	Understanding and interpreting weather information can be critical to the success of any winter snow and ice removal operation. Knowing when, where and what type of deicing material to use for a particular winter weather event can be a challenge. Knowing where to find the weather information needed to make decisions and what information to use can also be difficult. The Maintenance Division of the Iowa DOT has taken a number of steps to provide supervisors and operators with the weather information and training they need to make better operational decisions. A fifty-site RWIS coupled with a satellite delivered weather information system at nearly every maintenance garage have been sources for real-time weather information.	http://www.ctre.iastate.edu/pubs/midcon/front.pdf
ITS APPLICATIONS FOR SNOW AND ICE CONTROL	Paper describes potential applications of ITS for winter maintenance and provides case studies.	7th World Congress on ITS (1026.pdf), Michigan State University
ITS INSTITUTIONAL ISSUES: A MAINTENANCE/OPERATIONS PERSPECTIVE	Details challenges of using advance technology to optimize resources. Personnel, training, and cost issues are discussed. The Aurora-sponsored project found that, particularly with RWIS, the proprietary nature of new technologies tends to hold public agencies to using equipment from a single vendor.	http://www.ctre.iastate.edu/pubs/midcon/Smithso2.pdf
LOSS OF LIFE IN THE UNITED STATES ASSOCIATED WITH RECENT ATLANTIC TROPICAL CYCLONES	Freshwater floods caused more than half of US deaths directly associated with tropical cyclones or their remnants during the 30-year period from 1970 to1999. Most fatalities occurred in inland counties. Statistical summary of casualties, reasons for losses, and review of efforts to mitigate threats.	http://www.ametsoc.org/AMS/amsnews/aug282000.html
MANAGEMENT OF ROADS IN WINTER USING CCTV CAMERA	A snowfall forecast system collecting and analyzing numerical data has been installed in Sapporo. A System for Managing Frozen Road Surface Using CCTV Camera enables real time monitoring of remote conditions. A system using CCTV images and ESS was developed to complement patrols and support efficient winter maintenance.	8th World Congress on ITS; Office Community Service Bureau, City of Sapporo, Japan

TITLE	ABSTRACT	SOURCE
MANUAL OF PRACTICE FOR AN EFFECTIVE ANTI-ICING PROGRAM: A GUIDE FOR HIGHWAY WINTER MAINTENANCE PERSONNEL	Highway anti-icing is the snow and ice control practice of preventing the formation or development of bonded snow and ice by timely applications of a chemical freezing-point depressant. This manual provides information for successful implementation of an effective highway anti-icing program. It is written to guide the maintenance manager in developing a systematic and efficient practice for maintaining roads in the best conditions possible during a winter storm. It describes the significant factors that should be understood and must be addressed in an anti-icing program, with the recognition that the development of the program must be based on the specific needs of the site or region within its reach. The manual includes recommendations for anti-icing practices and guidance for conducting anti-icing operations during specific precipitation and weather events.	http://www.fhwa.dot.gov/reports/mopeap/eapcov.htm
MEASUREMENT OF MOTORIST'S RELATIVE VISIBILITY INDEX (MRVI) THROUGH VIDEO IMAGES	This paper introduces a new road visibility index referred to as the motorists' relative visibility index (MRVI). This index represents the amount of visual information lost to the view of motorists due to atmospheric conditions in relation to the visual information available on an ideal clear day. MRVI is computed using readily available video images of roadways using relatively simple image processing techniques. MRVI is a road condition indicator and can be used for control of DMS, analysis of visibility effects on motorists, road closure decisions, and for fast identification of low visibility areas or time periods from a very large set of images collected from multiple video cameras.	Transportation Research Board 81st Annual Meeting, Search TRIS http://199.79.179.82/sundev/search.cfm
MOBILITY AND SAFETY IMPACTS OF WINTER STORM EVENTS IN A FREEWAY ENVIRONMENT: FINAL REPORT	The main goal of the research project summarized in this report was the investigation of winter storm event impacts on the volume, safety and speed characteristics of interstate traffic flow. A literature review of weather related speed and trip choice factors, RWIS and traveler information dissemination was completed. . The models that resulted from this research can be applied in conjunction with each other to produce expected winter storm event volume and speed reductions (i.e., event travel and delay impacts), and crash increases (i.e., event safety impacts).	http://www.ctre.iastate.edu/pubs/midcon/front.pdf
MODIFYING SIGNAL TIMING DURING INCLEMENT WEATHER	The largest decrease in vehicle performance occurs when snow and slush begins to accumulate on the road surface. Saturation flows (capacity) decrease by 20%, speeds decrease by 30%, and start-up lost times increase by 23%.	Transportation Research Board 80th Annual Meeting, University of Utah
MULTI-FUNCTIONAL DEPLOYMENT OF AHS KEY TECHNOLOGY	Overview of state of development of key technologies for Advanced Cruise-Assist Highway System (AHS). Users services of AHS include support for road surface condition information. The functions required from road surface condition sensors are dry, wet, water film, new snow, packed snow, slush, packed snow ice sheet, and ice film. Laser radar sensors and millimeter wave radio meters are non-contact sensors able to detect road condition states.	Ministry of Construction, Japan

TITLE	ABSTRACT	SOURCE
NATIONAL REVIEW OF HURRICANE EVACUATION PLANS AND POLICIES: A COMPARISON AND CONTRAST OF STATE PRACTICES: DRAFT	National review of evacuation plans and practices including literature review, and survey of DOT and emergency management officials in coastal states. Focus on current state practices, use of reverse flow operations and ITS, management policies, information exchange methods and decision-making criteria.	http://www.hurricane.lsu.edu/
OPERATOR INTERFACE DESIGN OF A LANE AWARENESS SYSTEM FOR SNOW REMOVAL OPERATIONS	Research conducted on a two-lane, rural state highway in Minnesota in low visibility conditions. Vehicle-mounted, magnetic, lane-tracking system displaying lane position through a prototype user interface with continuous visual reference to centerline or shoulder line, as well as peripheral modalities (i.e., directional seat vibration, peripheral visual displays in windshield corners, and an optional auditory warning). Could result in improved safety of operator and public, improved service levels (mobility) and reduced cost for snow removal operation operations and reduced economic impact on region (productivity).	7th World Congress on ITS, University of Iowa
OPTIMAL CONTROL OF VARIABLE SPEED LIMITS AND ROAD LIGHTING BASED ON PREDICTED SHORT TERM SOCIO-ECONOMIC IMPACTS	In research conducted on a 6 km rural, two-lane road section in Finland during low visibility and winter weather conditions, information on traffic and weather conditions is input to a control system that executes the optimal decision (varying speed limits and roadway lighting intensity) on each road sections. The control system minimizes socio-economic costs (vehicle, time, environmental, lighting and crash costs), while maintaining an acceptable level of service.	7th World Congress on ITS; Helsinki Traffic Information Centre of FinnRA, Finland
PERCOSTATION FOR REAL TIME MONITORING MOISTURE VARIATIONS, FROST DEPTH AND SPRING THAW WEAKENING	This paper presents the findings of the research and product development project, in which percostation (the road structure moisture, frost depth and spring law weakening monitoring station) was installed on a road in Rovaniemi, Finland. Percostation can be used to assist road officials in tracking real-time moisture levels, depth of the frost and especially the risk for the permanent deformations in the road structure during the spring thaw season. Based on the percostation measurement results, road officials can make decisions about measures to preserve the state of the road during critical conditions, for example by imposing weight restrictions during the worst thaw softening period.	Transportation Research Board 81st Annual Meeting, Search TRIS http://199.79.179.82/sundev/search.cfm

TITLE	ABSTRACT	SOURCE
PREDICTION OF DAILY TEMPERATURE PROFILE IN FLEXIBLE PAVEMENTS	The majority of previously published research on pavement temperature prediction has focused on predicting the annual maximum or minimum pavement temperature so as to recommend a suitable asphalt binder performance grade. However, modeling the pavement temperature on a daily or hourly basis has only been recently investigated. To determine the pavement temperature profile, the influence of ambient temperature and seasonal changes must be understood such that the effects of heating and cooling trends within the pavement structure can be quantified. In addition, the influence of different pavement structures on the temperature distribution within the pavement structure must be determined. This paper presents the temperature profile monitoring of flexible pavements on the Virginia Smart Road from March 2000 through May 2001. Developed models to predict the daily maximum and minimum temperature at depths to 0.188m within the pavement structure are presented.	Transportation Research Board 81st Annual Meeting, Search TRIS http://199.79.179.82/sundev/search.cfm
PROCEEDINGS FOR THE WEATHER INFORMATION FOR SURFACE TRANSPORTATION: DELIVERING IMPROVED SAFETY AND EFFICIENCY FOR TOMORROW	Symposium attended by a cross-section of transportation and weather professionals to establish national needs and requirements for weather information associated with decision-making actions involving surface transportation. See also WEATHER INFORMATION FOR SURFACE TRANSPORTATION (WIST): ESTABLISHING THE NATIONAL NEEDS AND REQUIREMENTS.	www.ofcm.gov/wist_proceedings/pdf/toc.pdf
PROCEEDINGS OF THE WORKSHOP ON STRATEGY FOR PROVIDING ATMOSPHERIC INFORMATION	The purpose of the workshop was to address issues identified in studies conducted by OFCM and the National Research Council (NRC). The workshop examined how the ever-increasing inventory of atmospheric information could be accessed and used by those who need it. The issue was divided into two parts: getting the information to where it is needed, and insuring that users can read and understand that information.	http://www.ofcm.gov/sai/proceedings/pdf/00_opening.pdf
REAL TIME FORECASTING OF HURRICANE WINDS AND FLOODING	Forecasting system developed to support emergency preparedness, evacuation and sheltering decisions in Louisiana.	http://www.hurricane.lsu.edu/_unzipped/suhayda_paper1/suhayda_paper1.pdf
REMOTE SENSING AND EMERGENCY MANAGEMENT FOR COASTAL ENVIRONMENTAL DISASTERS	Natural coastal hazard include inundation events, erosion events, circulation and depositional processes, and biological hazards.	http://www.hurricane.lsu.edu/_unzipped/huh_paper1/huh_paper1.pdf

TITLE	ABSTRACT	SOURCE
REMOTE SENSING FOR TRANSPORTATION: REPORT OF A CONFERENCE	Proceedings summarize highlights from the conference held in December 2000. Sponsors include USDOT RSPA, NASA, AASHTO & National States Geographic Information Council. Themes of university consortia include Traffic Surveillance, Monitoring and Management; Environment Assessment, Integration and Streamlining; Transportation Infrastructure Management; and Disaster Assessment, Safety, and Hazards (DASH). The DASH theme includes flood, fog, snow, tornado and earthquake events.	http://gulliver.trb.org/publications/conf/reports/remote_sensing_1.pdf
REUNION ISLAND'S MERLIN PROJECT: AN ITS IMPLEMENTATION SUCCESS STORY	In response to rock falls triggered by torrential rains and high winds over a coastal road on Reunion Island (a French territory) in the Indian Ocean, traffic managers use automatic lane closure barriers on lanes near cliff and movable barriers to delineate travel lanes on remainder of road. From the TCC, they collect traffic and weather data and disseminate information via DMS. This technique increases safety by separating opposing traffic flows, reducing speed limits, and reducing incident response times.	7th World Congress on ITS, Direction Departementale de l'Equipement, France
REVIEW OF THE INSTITUTIONAL ISSUES RELATING TO ROAD WEATHER INFORMATION SYSTEMS (RWIS): FINAL REPORT	Review of existing documentation of RWIS institutional issues including funding, staffing, partnering and the expandability, transferability, and compatibility of RWIS. Explore coordination and standardization issues of RWIS. Status of RWIS developments in various agencies. Experiences in implementing and deploying RWIS.	http://www.aurora-program.org/pdf/inst_issues.pdf
ROAD WEATHER INFORMATION SYSTEM (RWIS): ENABLING PROACTIVE MAINTENANCE PRACTICES IN WASHINGTON STATE	Washington State DOT's "rWeather" program has integrated and expanded the capabilities of RWIS in the state, enabling proactive winter maintenance practices and better informed winter travel decisions. Report reviews potential benefits of a comprehensive, integrated RWIS; examines use and opinions of RWIS by maintenance personnel; identifies barriers to expanded use of RWIS technologies; and evaluates public response to the "rWeather" traveler information website.	http://www.wsdot.wa.gov/PPSC/Research/CompleteReports/WARD529_1RWISEval.pdf
ROAD WEATHER INFORMATION SYSTEMS: SOME FINDINGS ON HOW RWIS INFORMATION SHOULD BE DISSEMINATED TO THE TRAVELING PUBLIC	Survey of four potential user groups of RWIS information: commuters, recreational travelers, long distance travelers, and truckers. Results show that DMS, commercial radio and HAR are the most popular delivery methods. Road condition information (e.g., accumulating snow, fog, ice, wind and road closures) is preferred over information on alternate routes, travel times, or travel speeds. Preferred delivery times are one hour before departure and while en-route.	Transportation Research Board 80th Annual Meeting, Search TRIS http://199.79.179.82/sundev/search.cfm
ROAD WEATHER REQUIREMENTS: EXECUTIVE SUMMARY	The first phase of the Surface Transportation Weather Decision Support Requirements (STWDSR) project documented needs for decision suppor by operators and users who must content with weather threaths on the surface transportation system. The second phase defined the high level requirements for decision support to winter road maintenance, and is the basis for on-going development. This executive summary describes the main results of these two phases and their relation to on-going projects.	Contact itspubs@fhwa.dot.gov

TITLE	ABSTRACT	SOURCE
RURAL FREEWAY MANAGEMENT DURING SNOW EVENTS - ITS APPLICATION	Based upon visibility, road surface conditions, and capacity of towns to accommodate motorists; the Minnesota DOT and law enforcement personnel activate warning sign, lower (or swing) gate arm, and activate gate lights to prohibit access to rural interstate freeways. Law enforcement personnel are positioned at gate location during closing and reopening. Systematic and well-coordinated plan for closing and reopening has reduced delay (mobility), accident frequency (safety), and lowered DOT costs to clear and reopen by 15% (productivity). Significant time savings result in less overtime pay. Future plans include the addition of fixed and portable DMS, CCTV cameras, and an electronic map.	7th World Congress on ITS, Minnesota DOT
RURAL ITS APPLICATIONS FOR SNOW MAINTENANCE AND WINTER HAZARD MITIGATION	Presents emerging ITS concepts and products for winter maintenance safety developed from the Ideas Deserving Exploratory Analysis (IDEA) program managed by Transportation Research Board. Includes fleet management, avalanche detection and gateway management system, fiber-optic-based visibility information system, and road condition sensor system concepts/products.	Transportation Research Board, Search TRIS http://199.79.179.82/sundev/search.cfm
SIGNS OF RAIN	The New South Wales Roads and Traffic Authority has expanded DMS use to warn motorists during wet weather conditions.	8th World Congress on ITS
SNOW & ICE CONTROL OPERATIONS	Describes various aspects of Caltrans' methods of controlling snow/ice on mountainous highways, including chain controls, materials, environmental concerns, equipment, personnel management, communications, forecasting, enforcement, and avalanche control.	www.dot.ca.gov/hq/roadinfo/snwicecontrol.pdf
SNOW EMERGENCY VEHICLE ROUTING WITH ROUTE CONTINUITY CONSTRAINTS	This paper summarizes new results from continuing research dealing with development of a decision support system for assisting the Maryland State Highway Administration Office of Maintenance staff in designing snow emergancy routes for Calvert County. By taking into account some of the more realistic constraints, we try to solve two problems. One involves minimizing the total number of trucks and, the second one involves minimizing the total deadhead distance given the number of trucks. The two problems do not result in identical solutions in general. Some application results are also reported which indicate using such a system can achieve improvements in service and savings in operational costs.	Transportation Research Board 81st Annual Meeting, Search TRIS http://199.79.179.82/sundev/search.cfm

TITLE	ABSTRACT	SOURCE
SOCIOECONOMIC IMPACTS OF HEAVY PRECIPITATION IN THE UNITED STATES	Flood losses rank just behind hurricane losses as the second greatest cause of economic losses from weather, and flood losses continue to grow. The number of lives lost due to flooding is decreasing but still ranks as the third highest cause of death ranking behind heat waves and lightning. Heavy rain in the Chicago metro area create rain-slick streets and highways causing three times the number of crashes than occur in light rain conditions. They also cause a 25% increase in the number of fatalities.	American Meteorological Society Conference Proceedings
SOUTHEAST UNITED STATES HURRICANE EVACUATION TRAFFIC STUDY	Study to address problems during the Hurricane Floyd evacuation. The study documents behavioral analysis, Evacuation Travel Demand Forecast Model, reverse lane standards, and ITS strategies.	www.fhwaetis.com/etis
STATE OF THE PRACTICE AND REVIEW OF THE LITERATION: SURVEY OF FOG COUNTERMEASURES PLANNED OR IN USE BY OTHER STATES	DOTs from 49 states (all but Virginia) were contacted in an effort to document the fog countermeasures that are currently in use or being planned by the other states. The results are presented in the report, along with the contact name and phone number or email address for each state.	Virginia Tech Research Council
SURFACE TRANSPORTATION WEATHER APPLICATIONS	Weather threatens surface transportation nationwide and impacts roadway mobility, safety, and productivity. There is a perception that traffic managers can do little about weather. However, three types of mitigation measures—control, treatment, and advisory strategies—may be employed in response to weather threats. Road weather data sharing, analysis, and integration are critical to the development of better road weather management strategies. Environmental information serves as decision support to traffic, maintenance, and emergency managers; and allows motorists to cope with weather effects through trip deferrals, route detours, or driving behavior.	Institute of Transportation Engineers 2002 Annual Meeting, Mitretek Systems ITS Division
SURFACE TRANSPORTATION WEATHER DECISION SUPPORT REQUIREMENTS	This series of documents presents the latest findings of the ongoing Surface Transportation Weather Decision Support Requirements (STWDSR) project. STWDSR Draft Version 1.0 documents the weather information requirements of all road users and operators. STWDSR Draft Version 2.0 focuses on the decision support requirements of a particular stakeholder group--winter road maintenance engineers. It also presents an operational concept for a Weather Information for Surface Transportation Decision Support System (WIST-DSS).	http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/94f01!.pdf, http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/9dc01!.pdf, http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/9db01!.pdf, http://www.itsdocs.fhwa.dot.gov/jpodocs/EDLBrow/401!.pdf, http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/@701!.pdf
SYNTHESIS OF ROAD WEATHER FORECASTING	Survey to document relationships between national surface transportation agencies and meteorological agencies. The countries of Canada, Denmark, Finland, Germany, Japan, New Zealand, Norway, Sweden and the United Kingdom were surveyed.	www.aurora-program.org/pdf/synthesis_weather.pdf

TITLE	ABSTRACT	SOURCE
SYSTEM MONITORS FLOOD-PRONE CREEKS	The City of Palo Alto, California maintains a "Creek Level Monitor" website that displays water levels at five bridge locations. The system detects water levels with ultrasonic devices under bridges and transmits data to the communication system that controls storm pump stations. City residents receive advanced warning of flood conditions.	www.civic.com/civic/articles/2001/0122/web-flood-01-26-01.asp
TEMPERATURE AND HUMIDITY EFFECTS ON THE CO-EFFICIENT OF FRICTION VALUE AFTER APPLICATION OF LIQUID ANTI-ICING CHEMICALS	Experiment conducted in Canada to establish the reliance of various anti-icing chemicals based on temperature and humidity; specifically to determine what roll they play on road co-efficient of friction. Research showed that when most anti-icing chemicals transition from liquid to solid, and solid to liquid, a "slurry" phase is formed; producing relatively short-lived reductions in friction co-efficient.	http://www.wsdot.wa.gov/fossc/maint/pns/pdf/slicknessrpt.pdf
TESTING THE ADVERSE VISIBILITY INFORMATION SYSTEM EVALUATION (ADVISE) - SAFER DRIVING IN FOG	There are many advisory systems to warn drivers of fog. However, warning drivers that there is fog ahead does not instruct them on what to do. During the 1995-2000 winter seasons, a new technology known as the Adverse Visibility Information System Evaluation (ADVISE) was tested. ADVISE uses visibility sensors to determine current sight distance and corresponding safe speed for the prevailing conditions. DMS instruct drivers of safe speed. This research measures the effectiveness of the system in reducing the variability between speeds. ADVISE successfully reduced speed variability by an average 22%.	Transportation Research Board 81st Annual Meeting, Search TRIS http://199.79.179.82/sundev/search.cfm
THE ADVANCED TRANSPORTATION WEATHER INFORMATION SYSTEM (ATWIS)	The Advanced Transportation Weather Information System (ATWIS) project was designed to provide a current road and forecasted weather report to the traveling public and commercial vehicles within North and South Dakota. This prototype project was to investigate how to merge information and current technologies from both state and private industry to provide in-vehicle decision support data for the traveler. The ATWIS was conceived and designed to provide information specifically for ground transportation, its users and maintainers. This paper examines the development and operational history of the multi-state ATIS.	http://www.ctre.iastate.edu/pubs/midcon/front.pdf
THE EFFECT OF VARIABLE MESSAGE SIGNS ON THE RELATIONSHIP BETWEEN MEAN SPEEDS AND SPEED DEVIATIONS	This research studies the effect of DMS on the relationship between hourly cross-sectional mean speeds and speed deviations. This section of I-90 in the vicinity of Snoqualmie pass, Washington is a rural freeway location subject to adverse weather conditions, and experiences over seventy-five reported vehicle crashes annually. DMS were installed to reduce crash potential by effective speed and traffic flow management. Aggregate results on vehicle speeds and vehicle speed deviations at the hourly level show that there is a significant decrease in mean speed when the DMS are on, along with a significant increase in speed deviation.	Transportation Research Board 81st Annual Meeting, Search TRIS http://199.79.179.82/sundev/search.cfm

TITLE	ABSTRACT	SOURCE
THE EFFECT OF WEATHER ON FREE FLOW SPEED	Free flow speed is affected by pavement conditions, visibility and wind speeds. The effects of poor weather should be considered in such cases as part of capacity and level-of-service analyses.	Transportation Research Board 80th Annual Meeting, Search TRIS http://199.79.179.82/sundev/search.cfm
THE MEASUREMENT AND THEORY OF TIRE FRICTION ON CONTAMINATED SURFACES	Summarizes results of various studies related to friction characteristics of wet, snowy and icy pavement. Preliminary project showed that modeling constants can be used to differentiate contaminates (water, snow, ice), and that friction levels can be monitored for salting control.	http://www.ctre.iastate.edu/pubs/crossroads/94measurement.pdf
THE USE OF ABRASIVES IN WINTER MAINTENANCE: FINAL REPORT OF PROJECT TR 434	Report reviews the state of the practice of abrasive usage in Iowa counties and classifies usage according to effectiveness.	www.sicop.net/Abrasives%20report.pdf
THE USE OF MOBILE VIDEO DATA COLLECTION EQUIPMENT TO INVESTIGATE WINTER WEATHER VEHICLE SPEEDS	Research involves traffic and weather data (i.e., visibility, roadway snow cover, volume, speed, and headway/gap data) collected by a trailer-mounted video data collection/monitoring system. Collected data used to predict vehicle speed and speed variability. Results indicate that average winter weather speed was 16% lower than that in speed under dry conditions. In winter weather, speed variation was 307% higher than variation during dry conditions. The resulting model predicted that off-peak winter weather speeds would decrease by 3.9 mph when visibility fell below one-quarter mile, and decrease by 7.3 mph when snow began to cover roadway lanes.	Transportation Research Board 79th Annual Meeting, Search TRIS http://199.79.179.82/sundev/search.cfm
TRAFFIC MODELING FRAMEWORK FOR HURRICANE EVACUATION	Development of computer-based incident management decision aid system (IMDAS).	Transportation Research Board 80th Annual Meeting, Search TRIS http://199.79.179.82/sundev/search.cfm
TRAVELAID	Report discusses effectiveness of DMS and in-vehicle traffic advisory systems (IVUs) on a mountainous pass for changing driver behavior. DMS and VSL signs were installed on I-90 to provide speed limit, weather, and roadway information to motorists in order to reduce the number and severity of crashes. Report includes analysis of mean speeds and speed deviation based upon a driving simulator study.	www.itsdocs.fhwa.dot.gov//jpodocs/repts_te//13610.html

TITLE	ABSTRACT	SOURCE
USE OF EXPERT SYSTEMS FOR ROADWAY WEATHER MAINTENANCE DECISIONS	Automated systems for forecasting frost and fog on roads and bridges using expert systems were deployed in Iowa.	http://www.ctre.iastate.edu/pubs/semisesq/session5/takle/
USE OF PAVEMENT TEMPERATURE MEASUREMENTS FOR WINTER MAINTENANCE DECISIONS	Analyzed pavement temperature data from urban and rural sites on bridges and roads to evaluate nighttime trends and differences of temperature at different locations under different weather conditions. Using RWIS pavement temperature data and cloud cover data from Jan. 1997, temperature differences, cooling rates, and lag times between urban and rural sites were computed.	http://www.ctre.iastate.edu/pubs/crossroads/33use.pdf
VARIABLE SPEED CONTROL: TECHNOLOGIES AND PRACTICE	Static speed limit signs fail to provide accurate information on speed selection when traffic and environmental conditions are less than ideal. Paper documents findings from a state-of-the-practice review on VSL systems. Paper reviews and compares characteristics of VSL systems, and discusses potential benefits and limitations associated with their deployment.	ITS America 11th Annual Meeting Proceedings, Michigan State University
VIDEO CAMERAS FOCUS ON VISIBILITY	A researcher has developed a technique for automatically measuring visibility with video cameras. The camera is aligned to detect contrasting portions of targets in order to generate a signal indicative of contrast levels. A processor uses the signal to compute visibility. Prototype system was installed on northbound Highway 35 near Duluth, Minnesota.	www.its.umn.edu/news/visibility.html
VISION AND CHALLENGES OF INTEGRATING TRAFFIC MANAGEMENT AND EMERGENCY RESPONSE SYSTEMS	There is a vision of a completely integrated public safety, emergency management system, and traffic management communications system that would save lives, reduce serious injuries, conserve public safety resources, and improve transportation efficiency. Various enablers and barriers to an Integrated Traffic Management and Emergency Response System (ITMERS) are discussed.	www.itsa.org/itsview.html
WEATHER BASED TRAFFIC MANAGEMENT APPLICATIONS IN NEVADA	Maintenance operations dealing with inclement weather occur at almost all levels of government across the United States. Several operational strategies and technologies have been developed to assist in the forecasting and detection of roadway conditions associated with inclement weather. RWIS technologies have become a cornerstone to several traffic management applications in northern Nevada. Detection of road and weather conditions allow for the development of detection and warning systems to alert motorists of potential driving difficulties of intermittent hazards.	Institute of Transportation Engineers 2002, Nevada DOT

TITLE	ABSTRACT	SOURCE
WEATHER IN THE INFO-STRUCTURE	This paper addresses the Weather Response component of the National Highway System Info-Structure and estimates an aggregate cost for national deployment. It does this by first documenting a methodology for determining the number of RWIS sensors needed across the country and then a methodology for determining the cost.	Cambridge Systematics, Inc.
WEATHER INFORMATION FOR SURFACE TRANSPORTATION (WIST I): ESTABLISHING THE NATIONAL NEEDS AND REQUIREMENTS	OFCM and FHWA initiated a project, within the federal meteorological community, to identify the nation weather needs and requirements for all surface transportation modes. Establishing initiatives, the Joint Action Group for WIST, database records, and plans for 2000 WIST Symposium are discussed.	http://www.ofcm.gov/wist_proceedings/proceedings.htm
WEATHER INFORMATION FOR SURFACE TRANSPORTATION (WIST II): ESTABLISHING THE NATIONAL NEEDS AND REQUIREMENTS	OFCM and FHWA initiated a project, within the federal meteorological community, to identify the national weather needs and requirements for all surface transportation modes. In this venue, surface transportation consists of roadways, rail, waterways, and pipelines. Noted shortcomings were the absence of definitive information on the spatial and temporal scales required for decision processes, and the lack of any specific threshold for identified weather elements.	http://www.ofcm.gov/wist2/proceedings2000/wist2startup.htm
WEATHER: A RESEARCH AGENDA FOR SURFACE TRANSPORTATION OPERATIONS	Weather crosscuts almost every goal, use, and operation of highways, and yet, meteorology, from a transportation perspective, is focused mostly on the flight operations. To make weather issues an important part of highway programs, people who manage highway operations must seek new techniques and ITS that complement the amazing system of weather-information collection, analysis, and forecasting that exists in the US.	http://www.tfhrc.gov/pubrds/02mar/05.htm
WEATHER: MAKING IT A NATIONAL PRIORITY IN SURFACE TRANSPORTATION	Includes "A National Program for Surface Transportation Weather Applications" by Pisano & Nelson; " An Advanced Winter Road Decision Support System" by Mahoney; "Research Needs in Weather Information for Surface Transportation--The Perspective of the User Community" by Nixon; "Utilizing FAA-Developed Automated Weather Algorithms for Improving Surface Transportation Operations in Adverse Weather" by Hallowell; "Foretell--Some Findings and their Research Implications" by Davies, Choudhry & Canales; "Future Growth of Surface Transportation Weather: An Academic Question" by Osborne; and "Private Sector Meteorology and ITS" by Smith.	www.ops.fhwa.dot.gov/weather/publications/its_america.pdf

TITLE	ABSTRACT	SOURCE
WHITE PAPER: AN INTEGRATED NETWORK OF TRANSPORTATION INFORMATION	The integrated network is the "infostructure" that facilitates monitoring, management, and operation of the entire transportation network. The integrated network will enable Road Weather Information and offer the opportunity (1) to detect and respond to regional crises, (2) for fewer and less severe crashes, (3) for better operator and user information, and (4) to reduce energy consumption and negative environmental impacts.	www.itsa.org/ITSNEWS.NSF/4e0650bef6193b3e852562350056a3a7/927cd5cae21c0ff085256b190049bd4e?OpenDocument
WINTER MAINTENANCE IN THOMPSON FALLS (MEMORANDUM)	Comparison of treatment strategies for a winter storm event in Thompson Falls, Montana.	Montana DOT
WINTER OPERATIONS WEATHER FORECASTS: DO THEY WORK FOR THE MAINTENANCE SHED SUPERVISOR?	An evaluation of Utah DOT's RWIS included validation of NWS forecasts and Northwest Weathernet forecasts for specific interstate corridors, and satisfaction surveys completed by maintenance supervisors.	Transportation Research Board 80th Annual Meeting, Search TRIS http://199.79.179.82/sundev/search.cfm
WINTER STORM EVENT VOLUME IMPACT ANALYSIS USING MULTIPLE SOURCE ARCHIVED MONITORING DATA	Paper discusses how data from several information management systems in Iowa were used to analyze the volume impacts of winter storms. Analysis indicated that winter storms decrease traffic volumes by 29% on average (range from 16% to 47%). Analysis revealed a relationship between percent volume reduction and total snowfall, minimum average wind speed and the square of maximum wind gust speed.	Transportation Research Board 79th Annual Meeting, Search TRIS http://199.79.179.82/sundev/search.cfm

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