ROAD WEATHER MANAGEMENT

STATE DOTS DISSEMINATE WEATHER WARNINGS TO PUBLIC TRAVELER INFORMATION AGENCIES IN 26 STATES, TRAFFIC MANAGEMENT AGENCIES IN 22 STATES, AND INCIDENT MANAGEMENT AGENCIES IN 21 STATES.

ROADWAYS

Adverse weather conditions pose a significant threat to the operation of the Nation's roads. According to the National Research Council, motorists endure more than 500 million hours of delay each year as a result of fog, snow, and ice.[186] Rain—which occurs more frequently than snow, ice, and fog—leads to greater delay. Furthermore, an investigation of vehicle crashes from 1995 through 2005 show that each year more than 673,000 people are injured and nearly 7,400 are killed in weather-related crashes.[187] The estimated cost of weather-related crashes ranges from $22 billion to $51 billion annually. These costs include travel delay, emergency services, property damage, medical and rehabilitation costs, productivity losses, insurance administration costs, legal and court costs, and the costs to employers.[188]

Adverse weather not only affects safety but can also degrade traffic flow and increase travel times. Under extreme conditions (such as snowstorms), travel times can increase by as much as 50 percent.[189]

The Road Weather Management program, within the Federal Highway Administration Office of Operations, is working to mitigate these impacts by developing strategies, tools, and technologies that promote safety, increase mobility, improve productivity, and protect the environment.

Agencies that operate and maintain roadways use surveillance, monitoring, and prediction to mitigate the impacts of adverse weather. Environmental sensor stations (ESS) and road weather information systems (RWIS) are used to provide transportation managers and maintenance personnel with actual and forecast weather and pavement condition data that can be used to implement advisory strategies, control strategies, and treatment strategies.

Information dissemination capabilities enable advisory strategies to provide information on prevailing and predicted conditions to both transportation managers and motorists. Posting fog warnings on dynamic message signs (DMS) and listing flooded routes on Web sites are examples of these advisory strategies.

Traffic control technologies enable agencies to enact control strategies that alter the state of roadway devices to permit or restrict traffic flow and regulate roadway capacity. Reducing speed limits with variable speed limit (VSL) signs and modifying traffic signal timing based on pavement conditions are examples of control strategies.

Response and treatment applications are designed to improve efficiency and the effectiveness of treatment strategies, typically snow and ice control operations involving the application of sand, salt, and anti-icing chemicals to pavements to improve traction and prevent ice bonding. Winter maintenance vehicles can be equipped with automatic vehicle location (AVL) systems and mobile sensors to monitor pavement conditions and optimize treatment application rates. In problem areas where the roadway can freeze unexpectedly, such as bridges in cold climates, fixed anti-icing/deicing systems can be installed and activated automatically based on ESS data.

Several other chapters of this report discuss ITS applications relevant to road weather management. The roadway operations and maintenance chapter discusses asset management technologies, such as AVL that can facilitate efficient winter road maintenance. Also, the traveler information chapter discusses technologies valuable for disseminating weather-related information to travelers.

ROAD WEATHER MANAGEMENT CATEGORIES IN THE ITS KNOWLEDGE RESOURCES

Surveillance, Monitoring, and Prediction

- Pavement Conditions
- Atmospheric Conditions
- Water Level

Information Dissemination—Advisory Strategies

- Dynamic Message Signs
- Internet/Wireless/Phone
- Highway Advisory Radio

Traffic Control—Control Strategies

- Variable Speed Limits
- Traffic Signal Control
- Lane Use/Road Closures
- Vehicle Restrictions

Response and Treatment—Treatment Strategies

- Fixed Winter Maintenance
- Mobile Winter Maintenance

EXPERIENCE WITH ANTI-ICING PROGRAMS HAS DEMONSTRATED CRASH RATE REDUCTIONS FROM 7 TO 83 PERCENT.

OTHER ITS KNOWLEDGE RESOURCE CATEGORIES RELATED TO ROAD WEATHER MANAGEMENT

Refer to other chapters in this document.

Roadway Operations and Maintenance

Asset Management

Traveler Information

Pre-Trip Information

En Route Information

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In addition to the technologies profiled in this chapter, two major road weather programs—the *Clarus* initiative and the Maintenance Decision Support System (MDSS)—have the potential to encourage the deployment of ESS and improve the availability and timeliness of high-quality road weather information. *Clarus* aims to leverage State DOT investments to create a road weather observation data management system that is national in scope. The initiative will build upon the RWIS that many state DOTs have been deploying for years, primarily in support of winter maintenance activities. MDSS is a decision support tool that integrates relevant road weather forecasts, maintenance rules of practice, and maintenance resource data to provide winter maintenance managers with recommended road treatment strategies.[190] Additional information on the *Clarus* initiative is available at the ITS JPO's Web site at *www.its.dot.gov/clarus* and information on the MDSS project is available on the Road Weather Management program Web site at *www.ops.fhwa.dot.gov/weather/mitigating_impacts/programs.htm#p3*.

Findings

Benefits

Evaluation data show that 80 to 94 percent of motorists who use traveler information Web sites think road weather information enhances their safety and prepares them for adverse road weather conditions.[191] Although quantitative impacts of road weather advisory systems are difficult to measure on a regional basis, warning systems that use flashers or DMS to alert drivers of reduced visibility or wind hazards have proven effective on short sections of roadway prone to these hazards.[192] Evaluation data show that drivers pay attention to these types of warning systems and will slow down or speed up as recommended to improve traffic speed uniformity and reduce crash risk.[193]

High-quality road weather information can benefit travelers, commercial vehicle operators, emergency responders, and agencies who construct, operate, and maintain roadways. RWIS are now a critical component of many agencies' winter maintenance programs. Accurate and timely road weather information helps maintenance managers react proactively before problems arise. Maintenance managers indicate that effective anti-icing and pre-wetting strategies reduce sanding applications by 20 to 30 percent, decrease chemical applications by 10 percent, and reduce chloride and sediment runoff in local waterways.[194] Evaluation data show that anti-icing programs can lower snow and ice control costs by 10 to 50 percent and reduce crash rates by 7 to 83 percent (figure 6).[195]

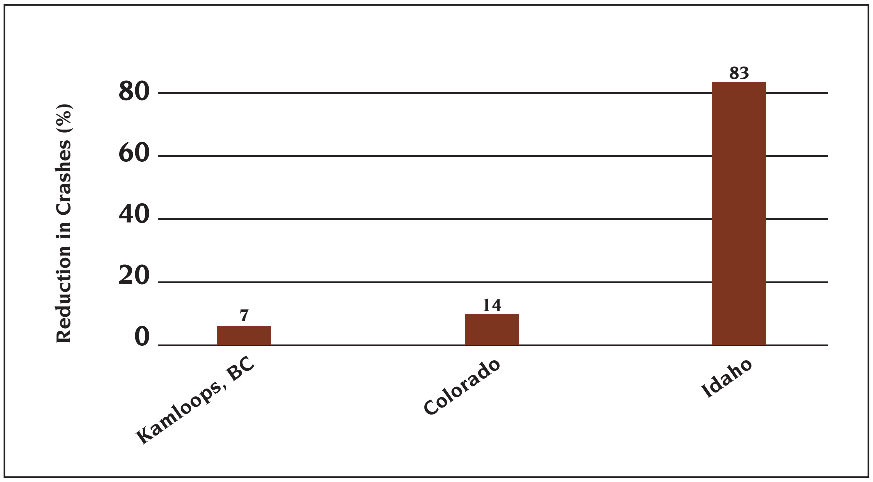

Figure 6 – Impact of Anti-Icing Programs on Weather Related Crashes

Table 5 presents qualitative ratings of the impact of road weather management ITS applications under each of the six ITS goals. All the strategies have been found effective in improving safety. Studies on the usage of surveillance technologies and treatment strategies have shown productivity improvements. Surveys have shown that both agency personnel and the general public are satisfied with road weather information dissemination.

Table 5—Road Weather Management Benefits Summary

	Safety	Mobility	Efficiency	Productivity	Energy and Environment	Customer Satisfaction
Surveillance, Monitoring, and Prediction	●			●		✚
Information Dissemination (Advisory Strategies)	●					✚
Traffic Control (Control Strategies)	✚					
Response and Treatment (Treatment Strategies)	●			✚	✚	

● Substantial positive impacts	✚ Positive impacts
❍ Negligible impacts	✱ Mixed results
✖ Negative impacts	**blank** Not enough data

DATA FROM FIVE STATES SHOW THAT THE ADDITION OF VARIOUS ADVANCED TECHNOLOGY APPLICATIONS SUCH AS RADAR, SENSORS, AND CONTROL UNITS CAN ADD $20,000 TO $30,000 TO THE COST OF A REGULAR SNOWPLOW.

Costs

As with most ITS deployments, costs of road weather management systems vary based on several factors, including their scope, complexity and particular technology or technologies under consideration. Often costs are estimated based on similar systems because precise records are not available and multiple organizations involved in the deployment make traceability from various funding sources difficult.

Automated wind warning systems were installed at two rural Oregon locations to alert motorists of high crosswind conditions. Each automated wind warning system is estimated to cost $90,000; annual operations and maintenance (O&M) costs are estimated at $3,000 to $3,500.[196]

Nine respondents to a fixed automated spray technology (FAST) survey indicated that cost of installations varied greatly, $22,000 to $4 million, depending on coverage area, site location, accessibility of existing utilities, system functionality and features, and market factors. O&M costs of FAST systems are relatively low compared to the installation costs.[197]

Based on data from early AVL implementers across the U.S., the capital costs of AVL systems are highly dependent on the level of software customization of commercial off-the-shelf packages, as well as the type of sensors installed on the maintenance vehicles and how the vehicle was equipped prior to the AVL installation. When the systems were installed was also a factor as the cost of AVL technology has dropped over time. Based on six deployments, the cost per vehicle ranged from $1,250 to $5,800. For several deployments, communications cost ranged from $40 to $60 per month per vehicle.[198] Data from five states show that the addition of various advanced technology applications such as radar, sensors, and control units can add $20,000 to $30,000 to the cost of a regular snowplow.[199]

Road weather information can be disseminated to travelers via several media. In January 2003, Montana DOT implemented its 511 system to provide travelers with traffic and road weather conditions. The 511 traveler information system is a part of the Greater Yellowstone Regional Travel and Weather Information Systems project. Annual operating costs for 2004 were $195,453 and for 2005 costs were $195,930. These costs included contracted services and equipment leases, toll charges, marketing, and operations for the statewide alert system.[200]

Benefit-Cost Studies

Several benefit-cost studies of road weather management technologies have been conducted and all found positive benefit-to-cost ratios. Staff meteorologists, stationed at the transportation management center in Salt Lake City, Utah, provided detailed weather forecast information to winter maintenance personnel, reducing labor and materials costs for snow and ice control activities and yielding a benefit-to-cost ratio of 10:1.[201] A study of a weather and road condition controlled system of VSL signs in Finland showed favorable results for deployment along highly trafficked road segments. Starting benefit-to-cost ratios ranged from 1.1:1 to 1.9:1. The ratio was higher if safety assumptions were higher and there was greater use of higher speed limits.[202] With more efficient application of anti-icing chemicals and abrasives, reduced maintenance costs, reduced delay, and increased safety; benefit-to-cost ratios for RWIS and anti-icing strategies range from 2:1 to 5:1.[203]

Deployment

A survey of each of the 50 states conducted in 2006 revealed that state DOTs collect weather information from ESS, the National Weather Service, and other sources and distribute it in real time to a variety of users. Table 6 shows the number of State DOTs that distribute weather warnings and forecasts to different types of organizations. State DOTs distribute real-time weather warnings most often with public traveler information agencies (26 states), followed by traffic management agencies (22 states), incident management agencies (21 states), state policy (17 states), and public safety agencies (16 states). State DOTs send weather warnings to data archives and to private traveler information organizations in six states; five State DOTs distribute weather warnings to other States. The distribution of weather forecasts follows a similar distribution pattern with about half as many State DOTs sharing this more detailed weather information as share simple weather warnings.

The 2006 survey of each of the 50 states about deployment of ITS technologies in rural areas and on a statewide basis is the source of deployment statistics presented later in this chapter, unless otherwise noted.

Table 6—Communication of Weather Warnings and Forecasts Statewide

Agency Type Receiving Real-Time Distribution of Weather Information	Number of State DOTs Sending Weather Warnings	Number of State DOTs Sending Weather Forecasts
Traveler Information—Public Sector	26	15
Incident Management	22	10
Traffic Management	21	10
State Police	17	8
Local Government	11	4
Public Safety	16	6
Data Archiving	6	5
Traveler Information—Private Sector	6	2
Other States	5	4

LESSONS LEARNED

Provide adequate training to maintenance crews in order to build support for the use of an advanced decision support tool.

The Maintenance Decision Support System deployed by the Maine Department of Transportation (MaineDOT) offered a useful winter storm planning tool that supplemented other resources in some important ways. First, the MDSS added capabilities that the agency previously did not have including pavement temperature forecast trends, bridge and pavement frost forecasts, and a tool that could provide pavement treatment recommendations based on an analysis of multiple weather parameters. Second, the MDSS offered an integrated platform for the display and analysis of National Weather Service forecasts in a user-friendly geographical information system format. MaineDOT found its experience overall with the MDSS to be a beneficial one.

(*Continued on next page.*)

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Selected Highlights from the ITS Knowledge Resources on Road Weather Management

Surveillance, Monitoring, and Prediction

Surveillance, monitoring, and prediction of weather and road conditions enable the appropriate management actions to mitigate the impacts of any adverse conditions.

Surveillance, Monitoring, and Prediction	
Deployment	
The use of sensors to track weather is popular among State DOTs. Thirty-eight (38) states use in-pavement or road sensors to track pavement conditions; the same number deploy ESS in rural areas. Fifteen (15) states use sensors to monitor water levels on roadways.	
Benefits	
ITS Goals	**Selected Findings**
Safety	In Vantage, Washington, the deployment of an automated anti-icing system on I-90 was projected to eliminate up to 80 percent of snow and ice related crashes.[204]
Productivity	Through the Utah DOT Weather Operations Program, meteorologists based at the transportation management center use information from ESS in the field to provide detailed forecasts to winter maintenance personnel, saving $2.2 million per year in labor and materials for snow and ice control activities. This reduction is approximately 18 percent of the 2004-2005 labor and material costs.[205]
Customer Satisfaction	In interviews following the deployment of two new ESS equipped with pole-mounted closed circuit television (CCTV) cameras and sensors to measure an array of environmental conditions, the Washington State DOT road maintenance crews ranked pavement condition data from ESS as the most useful information, followed by camera images, and radar data on the Internet. The maintenance superintendent reported that the ESS data and camera images helped staff become more productive by allowing them to check road conditions in outlying areas and minimizing unnecessary trips.[206]

Surveillance, Monitoring, and Prediction
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Roadside Detection subsystem: • Environmental Sensor Station (Weather Station): $30K-$49K • Closed Circuit Television (CCTV) Video Camera: $9K-$19K Transportation Management Center subsystem: • Road Weather Information System (RWIS): $11K Roadside Telecommunications subsystem: • Conduit Design and Installation—Corridor: $50K-$75K (per mile) • Fiber Optic Cable Installation: $20K-$52K (per mile)
Sample Costs of ITS Deployments
Oregon: Automated wind warning systems were installed at two rural Oregon locations to alert motorists of high crosswind conditions. Message signs are located at each end of the corridor or bridge where motorists can decide to wait until the winds die down or to take a longer alternative route. The systems, which are similar, consist of a local wind gauge (anemometer) with continuous input to a flashing beacon on a static message sign. Communication to the warning signs is automated and is provided by using dial-up phone service. The warning signs are activated when average wind speeds reach a predetermined threshold. The severity is automatically recorded. Once verified by staff at the transportation management center, a warning message is posted to the Oregon DOT TripChek Web site. The signs are deactivated when the wind speed drops below the threshold. Each automated wind warning system is estimated to cost **$90,000**; O&M costs are estimated to range from **$3,000 to $3,500 annually**.[207] **Ohio:** In 2003, the Ohio Department of Transportation (ODOT) expanded its RWIS with the addition of 86 environmental sensor stations to the 72 already in operation. The 158 ESS provide coverage of all 88 Ohio counties, making it the largest deployment of RWIS ESS in the U.S. Information from the ESS is processed by a central server located in Columbus. The data are used by ODOT maintenance personnel to make road treatment decisions to control snow and ice. Eighty-six (86) ESS were installed with 2 more sites planned in the following construction season. The deployment was contracted as a product purchase wherein the vendor was responsible for equipment installation. ODOT required that the ESS be compliant with the National Transportation Communications for ITS Protocol and support wireless communication. The contract also included a two-year service agreement (recurring costs over 2 years) for maintenance support 365 days a year, 24 hours a day, and 7 days a week with penalties imposed for down sites. ESS expansion cost totaled **$3.699 million** (2003).[208] **Maryland:** A fog detection system is being planned in response to a serious multi-vehicle crash that occurred in May 2003 along I-68 near Big Savage Mountain in Maryland. The new system will make use of existing infrastructure at two locations and includes a new RWIS. The existing RWIS at Big Savage and Keysers Ridge will be modified to identify low visibility conditions and alert drivers via warning signs. The third location, Friendsville, will be equipped with an ESS and warning signs. The cost to modify Big Savage and Keyser sites was **$75,000 per location**. The cost of new infrastructure at Friendsville was **$125,000**.[209]

LESSONS LEARNED

(Continued from previous page.)

Provide training to staff before introducing MDSS and provide ongoing support after implementation.

In order to achieve the full benefits of an MDSS, users need to fully understand how it works, how to interpret the information it offers, and how best to apply it in support of decision making. This type of training needs to occur before the tool is even introduced.

- Offer the MDSS tool initially to one of the State's more progressive crews.

An MDSS is more complex technology compared with many of the systems used throughout Maine and other States. MaineDOT selected Scarborough crews to test the new system based in part on their enthusiasm and willingness to work with the MDSS throughout the winter season. More progressive crews can serve as an example and can provide training to other crews.[212]

LESSONS LEARNED

Integrate weather information into transportation management center (TMC) operations to manage traffic in a more responsive and effective way during weather events.

Weather events have both major and minor impacts on transportation management operations. During seasonal weather events, these impacts may include reduced traffic flow or increased traffic incidents. At other times, natural disasters (such as hurricanes, blizzards, and severe summer storms) have major impacts on transportation management operations. During these events, major routing changes, dramatic traffic bottlenecks, or complete transportation shutdowns may occur. Integrating weather information and systems across multiple agencies and organizations can help TMCs conduct their operations more effectively. TMCs must evaluate which concepts and specific methods will work best for them in meeting their needs.

- Continuously update weather information.

TMCs should have an automated process or other robust structure in place for the continuous updating of weather information. While this function may be performed using weather information from the Internet, more highly-integrated methods include contractor-provided surface transportation weather forecasts, field observers or probes providing scheduled weather and driving condition information, and meteorology staff located within the TMC forecasting and interpreting weather information.[216]

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Surveillance, Monitoring, and Prediction
Benefit-Cost Studies
Utah: Staff meteorologists, stationed at the transportation management center in Salt Lake City provided detailed weather forecast information to winter maintenance personnel, reducing labor and materials costs for snow and ice control activities and yielding a benefit-to-cost ratio of 10:1.[210] **Oregon:** The benefit-to-cost ratios calculated for two automated wind warning systems deployed in Oregon were 4.13:1 and 22.80:1.[211]

Information Dissemination

Information dissemination technologies help road weather managers notify travelers of any adverse conditions.

Information Dissemination	
Deployment	
The Internet is the medium most commonly used by state agencies to disseminate weather information on a statewide basis; 37 states distribute weather information via Web sites. Other popular media for statewide distribution of weather information are DMS (reported by 29 states) and highway advisory radio (reported by 20 states). According to a 2006 survey of the country's 108 largest metropolitan areas, 49 metropolitan areas reported using DMS to disseminate weather advisories.	
Benefits	
ITS Goals	**Selected Findings**
Safety	A wet pavement detection system deployed on a temporary detour route along I-85 in North Carolina warned of wet pavement or standing water during rainstorms, yielding a 39 percent reduction in the yearly rate of crashes under wet conditions.[213]
Customer Satisfaction	Ninety-four (94) percent of surveyed users of a road weather information Web site covering roadways in Washington agree that the weather information made travelers better prepared for their trips. Over half of the respondents (56 percent) agreed the information helped them avoid travel delays.[214]

Information Dissemination
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Roadside Information subsystem: • Dynamic Message Sign: $48K-$119K • Portable Dynamic Message Sign: $18.6K-$24K • Highway Advisory Radio: $15K-$35K Transportation Management Center subsystem: • Software for Traffic Information Dissemination: $17K-$21K • Labor for Traffic Information Dissemination: $107K-$131K (annually) Roadside Telecommunications subsystem: • Conduit Design and Installation—Corridor: $50K-$75K (per mile) • Fiber Optic Cable Installation: $20K-$52K (per mile)
Sample Costs of ITS Deployments
Montana: In January 2003, Montana DOT implemented its 511 system to provide travelers with traffic and road weather conditions. The 511 traveler information system is a part of the Greater Yellowstone Regional Travel and Weather Information Systems project. The cost to implement the system was **$188,000** and included system development, voice recognition technology, marketing, and a one-time improvement for the addition of regional reports, AMBER (America's Missing: Broadcast Emergency Response) Alerts, homeland security alerts, and general transportation alerts. Operating costs for 2004 were **$195,453** and for 2005 costs were **$195,930**. These costs included contracted services and equipment leases, toll charges, marketing, and operating cost for the statewide alert system.[215]

Traffic Control

Traffic control technologies improve traveler safety under poor weather conditions. A variety of technologies allow these control measures to be taken quickly in response to developing adverse weather.

Traffic Control	
Deployment	
Almost half of all states (24) use ITS technologies to manage traffic diversions in response to road closures due to weather events. The same number of states use ESS to determine the need to implement temporary restrictions on vehicles. Eight states use VSL to respond to weather conditions.	
Benefits	
ITS Goals	**Selected Findings**
Safety	A VSL system implemented along I-75 in Tennessee to control traffic during foggy conditions, and close the freeway if necessary, has dramatically reduced crashes. While there had been over 200 crashes, 130 injuries, and 18 fatalities on this highway section since the interstate opened in 1973, a 2003 report noted that only one fog-related crash occurred on the freeway since installation of the system in 1994.[217]
Mobility	An investigative study sponsored by the Minnesota DOT found that optimizing traffic signals along an arterial corridor to accommodate adverse winter weather conditions yielded an eight percent reduction in delay. The study also noted that the existing signal timing plans were sufficient to accommodate the lower traffic volumes and lower speeds during winter weather.[218]
Productivity	During a 1998 snow storm, the Minnesota DOT reduced roadway clearance costs by 18 percent on I-90 by activating a freeway gate closure system to limit vehicle interference and reduce snow compaction problems that increase work for plows.[219]
Customer Satisfaction	Survey results in Finland indicate that 90 percent of drivers found weather-controlled VSL signs to be useful.[220]

Traffic Control
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Roadside Control subsystem: • Fixed Lane Signal: $5K-$6K • Signal Controller and Cabinet: $8K-$14K Roadside Detection subsystem: • Remote Traffic Microwave Sensor on Corridor: $9K-$13K per sensor • Environmental Sensor Station (Weather Station): $30K-$49K Roadside Information subsystem: • Dynamic Message Sign: $48K-$119K • Highway Advisory Radio: $15K-$35K Transportation Management Center subsystem: • Labor for Traffic Information Dissemination: $107K-$131K (annually) Roadside Telecommunications subsystem: • Conduit Design and Installation—Corridor: $50K-$75K (per mile) • Fiber Optic Cable Installation: $20K-$52K (per mile)
Sample Costs of ITS Deployments
Finland: Approximately 350 km of the main road network have been equipped with VSL signs; most systems are weather-controlled. The systems consist of DMS, ESS, traffic monitoring stations, and CCTV cameras. The number of units and spacing varies for dual carriageways and single carriageways. The average implementation costs on dual carriageways (divided highways) are **80,000 €/km** (almost double the amount for single carriageways (roadway with no physical separation)). Communications cabling is the major cost driver. Average maintenance costs for dual carriageways, which include replacement investments for a 20-year life, are **3,500 €/km/year**. Costs are at the 2004 level.[221]
Benefit-Cost Studies
Finland: A study of a weather and road condition controlled system of VSL signs in Finland showed favorable results for deployment along heavily traveled road segments. Starting benefit-to-cost ratios ranged from 1.1:1 to 1.9:1. The ratio was higher if safety assumptions were higher and there was greater use of higher speed limits.[222]

Response and Treatment

A variety of ITS applications are being deployed in the United States to support roadway treatments necessary in response to weather events. These applications may provide for automated treatment of the road surface at fixed locations, such as anti-icing systems mounted on bridges in cold climates. They may also enhance the efficiency and safety of mobile winter maintenance activities, for example, through AVL technologies on snow plows supporting a computer-aided dispatch system.

Response and Treatment	
Deployment	
Twenty (20) states use automatic bridge anti-icing systems and 13 states equip a portion of their snow plow fleet with AVL, communications, and sensors to track distribution of chemical treatments.	
Benefits	
ITS Goals	**Selected Findings**
Safety	***Summary Finding:*** Analysis of fixed anti-icing systems deployed on bridges in Utah, Minnesota, and Kentucky found crash reductions from 25 to 100 percent. [223]
Mobility	In Finland, an RWIS that automatically communicated actual and forecast data to road maintenance personnel was estimated to save an average of 23 minutes per deicing activity and improve traffic conditions. [224]
Productivity	Winter maintenance personnel indicated that anti-icing techniques limit snow/ice bonding on roadways, improve plow efficiency, reduce the time required to clear snow/ice from roadways, reduce maintenance costs (overtime pay and materials), and reduce the need for abrasive cleanup activities.[225]
Energy and Environment	Winter maintenance personnel from several agencies indicated that use of RWIS decreases salt usage and anti-icing techniques limit damage to roadside vegetation, groundwater, and air quality (in areas where abrasives are applied).[226]

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Response and Treatment
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Roadside Control subsystem: • Automatic Anti-icing System—Short Span: $22K • Automatic Anti-icing System—Long Span: $45K-$446K Roadside Detection subsystem: • Closed Circuit Television (CCTV) Video Camera: $9K-$19K Transportation Management Center subsystem: • Road Weather Information System (RWIS): $11K Roadside Telecommunications subsystem: • Conduit Design and Installation—Corridor: $50K-$75K (per mile) • Fiber Optic Cable Installation: $20K-$52K (per mile) • 900 MHz Spread Spectrum Radio: $8.2K (per link) • Wireless: $1.1K-$1.7K (annually)
Sample Costs of ITS Deployments
Utah and Canada: Nine respondents to a FAST survey indicated that cost of installations varied greatly, **$22,000 to $4 million**, depending on coverage area, site location, accessibility of existing utilities, system functionality and features, and market factors. Three installations illustrate the median cost range: A FAST installation on a bridge on I-315 in Utah cost **$250,000**. In Ontario, Canada, a demonstration FAST installation on a bridge and approach was **$300,000 Canadian dollar (CAD)** or **$14.20/ft^2 (CAD)**. Operating costs were **$15,000 (CAD)** or **$0.70/ ft^2 (CAD)**. For later FAST deployments in Ontario, the cost of the basic spray systems ranged from **$90/ft^2 (CAD)** to **$370/ft^2 (CAD)** on two-lane structures. The cost for the advanced RWIS station associated with each FAST deployment was estimated at **$93,000 (CAD)**. O&M costs of the FAST systems are relatively low compared to the installation costs.[227] **Kansas:** The Kansas DOT sponsored a study of the use of AVL technologies for highway maintenance activities, particularly snow removal. A statewide system equipping 585 vehicles was estimated to cost approximately **$9 million** and about **$800,000 per year** for maintenance. The implementation cost for a dedicated data channel to the existing 800 MHz radio system was estimated at **$6 million**. The high communications cost is consistent with other AVL deployments. The AVL unit cost is estimated at **$3,500 per vehicle**.[228]

Response and Treatment
Costs
United States: Based on data from early AVL implementers across the U.S., the capital costs of AVL systems are highly dependent on the level of software customization of commercial off-the-shelf packages as well as the type of sensors installed on the maintenance vehicles and how the vehicle was equipped prior to the AVL installation. When the systems were installed was also a factor as the cost of AVL technology has dropped over time. Based on six deployments, the cost ranged from **$1,250 to $5,800 per vehicle**. For several deployments, communications cost ranged from **$40 to $60 per month per vehicle**.[229] **Iowa, Pennsylvania, Wisconsin, Arizona, and California:** The addition of various advanced technology applications such as radar, sensors, and control units can add **$20,000 to $30,000** to the cost of a regular snowplow.[230]
Benefit-Cost Studies
Utah, Minnesota, and Kentucky: Analysis of fixed anti-icing systems deployed on bridges in Utah, Minnesota, and Kentucky found benefit-to-cost ratios of 1.8:1 to 3.4:1.[231] **Kansas:** A Kansas DOT study found that the application of AVL to highway winter maintenance vehicles could result in a benefit-to-cost ratio ranging from at least 2.6:1, using conservative assumptions, to 24:1 or higher based on moderate assumptions.[232] **Washington and Finland:** With more efficient application of anti-icing chemicals and abrasives, reduced maintenance costs, reduced delay, and increased safety, benefit-to-cost ratios for RWIS and anti-icing strategies range from 2:1 to 5:1.[233]

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186 *Where the Weather Meets the Road: A Research Agenda for Improving Road Weather Services*, The National Academy of Sciences, National Research Council. Washington, DC. April 2004.

187 "Road Weather Management Program," U.S. DOT Federal Highway Administration, Web site URL www.ops.fhwa.dot.gov/Weather/q1_roadimpact.htm. Last Accessed 20 February 2008.

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189 Goodwin, L. *Weather Impacts on Arterial Traffic Flow*, Mitretek Systems. Falls Church, VA. December 2002.

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